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August 1977

ELKINS MINE DRAINAGE POLLUTION CONTROL DEMONSTRATION PROJECT

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Program Report

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16. ABSTRACT

In 1964 several federal agencies in cooperation with the State of West Virginia initiated a project to demonstrate methods to control the pollution from abandoned underground and surface mines in the Roaring Creek-Grassy Run Watersheds near Elkins, West Virginia.

The Roaring Creek-Grassy Run watersheds contained 400 hectares of disturbed land, 1200 hectares of underground mine workings and discharged over 11 metric tons per day of acidity to the Tygart Valley River. The reclamation project was to demonstrate the effectiveness of mine seals, water diversion from underground workings, burial of acid-producing spoils and refuse, surface mine reclamation, and surface mine revegetation. Following a termination order in 1967, major efforts were directed away from the completion of the mine sealings and toward surface mining reclamation and revegetation. In July 1968 the reclamation work was completed with the reclamation and revegetation of 284 hectares of disturbed land and the construction of 101 mine seals.

Results of an extensive monitoring program revealed that some reduction in acidity load (as high as 20 percent during 1968 and 1969), and little if any in iron and sulfate loads and flow have occurred in Grassy Run. Roaring Creek had an insignificant change in flow as a result of water diversion, and a decrease of 5 to 16 percent in acidity and sulfate load. Biological recovery in both streams has been nonexistent except in some smaller subwatersheds. Good vegetative cover has been established on almost all of the disturbed areas. Legumes dominate in most areas after eight years. Tree survival and growth has been good.

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DEMONSTRATION PROJECT

by

Resource Extraction and Handling Division
Industrial Environmental Research Laboratory
Cincinnati, Ohio 45268

Edited by

PEDCo Environmental, Inc.
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INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollution impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes a demonstration project to correct the environmental damage from abandoned surface and underground coal mines. The methods utilized and their cost and effectiveness are reported. The main body of the report is a summary of all aspects of the project and should be of value to private, state and federal agencies planning and conducting mine drainage abatement projects for abandoned mines. The Appendix contains detailed data and information that should be of value for researchers and others wishing to better understand reasons for variations in costs, effectiveness, and mine drainage quality and quantity.

For further information the Resource Extraction and Handling Division can be contacted.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

Underground and surface coal mining operations have resulted in degradation of the environment. Past mining operations continue to pollute streams with acid, sediment, and heavy metal laden waters. Land disturbed during mining lies deluged, and useless. In 1964 several Federal agencies in cooperation with the State of West Virginia initiated a project to demonstrate methods to control the pollution from abandoned underground and surface mines in the Roaring Creek-Grassy Run watersheds near Elkins, West Virginia.

The Roaring Creek-Grassy Run watersheds contained 400 hectares of disturbed land, 1200 hectares of underground mine workings and discharged over 11 metric tons per day of acidity to the Tygart Valley River. The reclamation project was to demonstrate the effectiveness of mine seals, water diversion from underground workings, burial of acid-producing spoils and refuse, surface mine reclamation, and surface mine revegetation. Following a termination order in 1967, major efforts were directed away from the completion of the mine sealings and toward surface mining reclamation and revegetation. In July 1968 the reclamation work was completed with the reclamation and revegetation of 284 hectares of disturbed land and the construction of 101 mine seals.

Results of an extensive monitoring program revealed that some reduction in acidity load (as high as 20 percent during 1968 and 1969), and little if any in iron and sulfate loads and flow have occurred in Grassy Run. Roaring Creek had an insignificant change in flow as a result of water diversion, and a decrease of 5 to 16 percent in acidity and sulfate load. Biological recovery in both streams has been nonexistent except in some smaller subwatersheds. Good vegetative cover has been established on almost all of the disturbed areas. Legumes dominate in most areas after eight years. Tree survival and growth has been good.

Average reclamation costs (at 1967 prices) were as follows: surface mine reclamation - \$4,150/hectare, seal construction - \$4,140/seal, and revegetation - \$620/hectare.

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The Elkins Mine Drainage Demonstration project was a cooperative effort between the State of West Virginia, U.S. Bureau of Mines (USBM), U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (USFWS) (formerly U.S. Bureau of Sport Fisheries and Wildlife) and the U.S. Environmental Protection Agency (EPA) (formerly part of Department of Health, Education and Welfare and the Federal Water Quality Administration FWQA). The Soil and Conservation Service, U.S. Forest Service and Tygart Valley Soil Conservation District provided assistance in the revegetation aspects of the project.

Overall direction of the project was by William E. Bullard, FWQA. The project was originally directed by a Technical Committee made up of Lowell Van Den Berg, FWQA, Chairman; Steve Krickovic, USBM, Houston Woods, State of West Virginia, and George Whetstone, USGS. Other key individuals during the conduct of the project were Robert Scott, EPA, James Boyer and Charley Finely, USBM, Willard Spaulding, Jr., and Charles Burner, USFWS, Jack Gallaher, USGS, and Edward Henry and Ben Green, State of West Virginia.

This report was prepared by the following EPA personnel: Ronald D. Hill, Robert Scott, John Martin and Roger Wilmoth all of the Industrial Environmental Research Laboratory, Cincinnati, and Richard Warner of the Field Investigation Center, Denver. Richard O. Toftner, Jack Greber, and Anne Cassel, PEDCo Environmental, Cincinnati, edited and prepared the final draft of the report. Information and data collected by the cooperating agencies were used freely throughout the report.

SECTION 1

INTRODUCTION

It has long been known that coal mining activities often severely degrade the quality of nearby ground and surface waters, chiefly through acid drainage. Acid discharges are known to occur centuries after a mine has been closed and abandoned. In 1964 the Congress authorized funds for a demonstration project to demonstrate the efficiency and cost of mine sealing, water diversion channeling, and other procedures for reclamation of mined areas. This report describes a demonstration project undertaken jointly by U.S. Bureau of Mines, U.S. Geological Survey, U.S. Sport Fisheries and Wildlife (now U.S. Fish and Wildlife Service), U.S. Environmental Protection Agency, and the State of West Virginia in the vicinity of Elkins, West Virginia and known as the Elkins Mine Drainage Pollution Control Demonstration Project.

This report provides detailed background information concerning the mine drainage problem, the legislation and funding, the project site, and project objectives (Section 3).

It provides baseline information with respect to prereclamation conditions at the site, i.e., the effects of mining operations, topography, geology, and hydrology (Section 4).

Reclamation and revegetation procedures undertaken in the course of the project are described in Section 5, with information on costs of equipment and operations.

Section 6 describes postreclamation conditions at the site, as indicated in several site assessments since the project terminated in 1967. Detailed postreclamation analyses of the several watersheds encompassed by the project are given in the appendices, together with a detailed chronology and other information to support evaluation of the project and its results. In the appendices, the study area has been divided into smaller watersheds with detailed data presented for each of the units.

SECTION 2

SUMMARY AND CONCLUSIONS

A project was conducted near Elkins, West Virginia to demonstrate methods to control acid mine drainage (AMD) pollution resulting from inactive surface and underground coal mines. Methods to be demonstrated were: air sealing of underground mines, diversion of surface waters from underground mine workings, burial of acid-producing spoils and coal refuse, reclamation of surface mines and revegetation of surface mines. Because of a reduction in the air sealing portion of the project, air sealing could not be evaluated except at one small underground mine.

Conclusions drawn from this study were as follows:

1) Air sealing of one small underground mine resulted in the reduction in the oxygen to 7 percent temporarily with a final stable concentration of 13 to 15 percent. Average reduction in acidity, iron and sulfate after equilibrium was 51, 30, and 43 percent respectively.

2) Although the large underground mine (several thousand hectares) was not completely sealed and thus could not be monitored for the effectiveness of a sealing program, it was the conclusion of the investigators that a mine of this type was not applicable to the air sealing technique. This mine contained hundreds of openings by mine adits, shafts, and interconnections of surface and underground mine workings. In addition it contained thousands of subsidence areas, and numerous fractures, cracks, etc. as a result of mining. All of these avenues for air to enter the mine would have been impossible to seal within economic bounds. Thus with each change in barometric pressure, air moves in or out of the mine.

   If air sealing is to be effective in the reduction of acid mine drainage, then the mine would probably have to have these characteristics: a) minimum of adits, (b) thick consolidated overburden with no subsidence and limited fractures, (c) several hundred feet of consolidated material between the mine workings and the outside.

3) Direct evidence that water diversion was successful in reducing the volume of water discharging from the underground mine or increasing the surface runoff was not apparent from the data collected, because of the inadequacies of the monitoring system, (i.e., lack of continuous monitoring of stream discharges). Observations of increased peak flows and local flooding appear to indicate that the diversion was successful.

4) Acid mine drainage concentration and pollution loads were highly dependent on climatic conditions, especially precipitation. For this reason comparison of yearly or even monthly before and after reclamation water quality data was difficult. This finding is evident from the data which showed general improvement of the water quality throughout 1969 and 1970, but a decrease in 1971 as a result of one month of very high precipitation which resulted in the flushing of large volumes of AMD from the underground mines.

5) Those subwatersheds primarily impacted by surface and not underground mines showed the greatest improvement. Although good vegetation was established on most areas the residual acidity, sulfate and other ions remaining in the backfill material continued to leach for years after reclamation was completed.

6) Except for a few small areas a good vegetative growth was established on all reclaimed area. The addition of agricultural lime and fertilizer was greatly responsible for this success.

7) Grasses exhibiting the best growth were tall fescue, oat grass, orchard grass and Kentucky bluegrass. Weeping love grass was a good nurse crop and survived two years. Barley was also a good nurse crop. *Sericea lespedeza*, birdsfood trefoil and alsike were the dominant legumes.

8) Best tree survival and growth was obtained from European black alder. Pines, Japanese larch and black locust also were successful. Tulip poplar and white oak in general had poor survival where the spoil material was of poor quality.

9) Dense growth of grasses and legumes did not appear to affect the growth survival of the older and other trees that were taller than the grasses and legumes. Pine survival did not appear to be affected, but growth was probably slower because of competition from the grasses and legumes.

10) The stream biota in areas heavily polluted by acid mine drainage had limited numbers and diversity indicating a highly stressed condition. In those streams having improved water quality, greater populations of more sensitive species were present after reclamation.

11) Some reduction in acidity load (up to 20 percent) and little if any in iron and sulfate loads and flow have occurred in Grassy Run as a result of the reclamation efforts in the Roaring Creek watershed.

12) Roaring Creek had an insignificant change in flow as a result of water diversion, and a decrease of 5 to 16 percent in acidity and sulfate load.

13) Average reclamation costs were as follows: surface mine reclamation - \$4,150/hectare, seal construction - \$4,140/seal, and revegetation - \$620/hectare at 1967 prices.

SECTION 3

BACKGROUND

ACID MINE DRAINAGE OVERVIEW

Mining activities in the United States have long been recognized as major contributors to the pollution of ground and surface waters. One of the most serious pollution problems arising from mining activities is acid mine drainage resulting from the chemical reaction of sulfide minerals (commonly iron sulfides) and air in the presence of water. This type of reaction is common in coal mining areas since sulfur-bearing materials, usually pyrite or marcasite, are found in the coal seams themselves and in the overburden covering the coal.

Discharge of acid mine drainage from coal beds has polluted our streams and rivers since early times. The drainage pollutants affect water quality by lowering the pH, reducing natural alkalinity, increasing total hardness, and adding undesirable amounts of iron, manganese, aluminum, and sulfates. The tangible costs of this pollution are those involved in replacing equipment corroded by the acid water, costs of additional treatment at municipal and industrial water treatment plants, and costs resulting from damage by corrosion of steel culverts, bridge piers, locks, boat hulls, steel barges, pumps, and condensers. Intangible damages, which are real and important, include destruction of biological life of streams, reduction of property values, and restriction of the recreational uses of polluted streams.

The major problems of mine drainage occur in the anthracite and bituminous coal regions in Appalachia. Although significant mine drainage problems occur in specific areas of the western mining states, the overall problem is not as great as in the eastern states.

Acid mine drainage results from mining and emanates from both active or abandoned strip and underground mines. Pollution studies in Appalachia have revealed that inactive underground mines contribute 52 percent of the acid, active underground mines 19 percent, inactive surface mines 11 percent, and active surface mines 1 percent. Most of the remaining sources are in combination surface-underground mines (1).

Statistics are available which indicate how serious and widespread the problem of acid mine drainage is. The Bureau of Sport Fisheries and Wildlife canvassed state governments in 1963 to determine the effects of acid mine drainage on fish habitats. The poll showed that such pollution -- virtually all from coal mines -- had already eliminated fish in nearly 9654 kilometers of streams and 6075 hectares of ponds, lakes, and reservoirs in 20 states (2). In 1970, estimates by the Federal Water Quality Administration showed that more than 19,308 kilometers of streams in the United States were significantly degraded by mining related pollution. Of the total affected streams, 16,920 kilometers or approximately 88 percent of the damage was located in the Appalachian coal region. An additional 965 kilometers of streams reportedly were degraded by coal mining in states in the Illinois, Western Interior, and Rocky Mountain coal regions (3).

LEGISLATION, FUNDING AND SITE SELECTION

By the late 1950's and early 1960's acid mine drainage had become a subject of major concern to those involved in pollution abatement. In 1962 the Committee on Public Works, House of Representatives, in House Report No. 306 (87th Congress, 1st Session) requested the Secretary of the Department of Health, Education, and Welfare (DHEW) to undertake a study of water pollution caused by acid mine drainage. This study was made by the Department's Division of Water Supply and Pollution Control. The study report, submitted to the second session of the 87th Congress in April 1962, was reproduced as House Committee Print No. 18 (4). This report analyzed the nature and scope of the acid mine drainage problem and recommended procedures for lessening it. The recommendations were as follows:

"In keeping with the appraisal of the mine drainage problem it is recommended -

I. That a three-point concurrent program for dealing with the acid mine drainage problem be considered.

These are:

(a) A sealing program directed at sealing abandoned mine shafts and other drainage openings, surface cracks, crevices, and sink holes at acid-producing mines so located and so situated as to be amenable to seal construction.

(b) A stepped up research program in Federal, State, and interstate organizations for developing other measures applicable to those mines where sealing is not practical or effective.

(c) A stream and acid flow regulation program to be employed where sealing or other methods are unable to reduce the acid content of the stream sufficiently to meet water quality requirements for all legitimate purposes.

II. That implementation of recommendation No. I be preceded by demonstrations of procedures and results of acid mine drainage control in 3 appropriate watersheds containing between 50 and 100 abandoned coal mines each from which acid water is now draining, the demonstration work would be carried out under the supervision of the W.S. and P.C. program of the Department of Health, Education, and Welfare. The demonstration would be accompanied by an adequate measuring system to properly evaluate the results of the work. The cost for such demonstrations is estimated at $5 million.

III. That the Department of Health, Education, and Welfare in cooperation with other Federal water resources agencies proceed immediately under present legislation with a comprehensive program of water resources development including providing reservoir storage for the release of water for quality control purposes.

IV. That Federal and State water pollution control enforcement procedures be invoked where necessary to obtain pollution abatement of acid drainage from active mines.

V. That a continuing surveillance program with provision for maintenance be incorporated in legislative actions as a permanent measure of control under the Federal Water Pollution Control Act.

VI. That uniform State laws be adopted covering the control of acid mine or mine-related drainage.

VII. That the States take action to reclaim lands and water laid waste by present and future strip mining."

Public Law 87-88, 88th Congress, authorized initiation of the second recommendation, i.e., the demonstration program. The overall responsibility of the program was delegated to the Division of Water Supply and Pollution Control, U.S. Department of Health, Education and Welfare (DHEW). [In several reorganizations between 1962 and 1971, the group was known as the Federal Water Pollution Control Adminstration and the Federal Water Quality Administration; Federal water quality activities are now in the Environmental Protection Agency (EPA)]. Also to participate in the demonstration projects were the U.S. Bureau of Mines

(USBM), U.S. Geological Survey (USGS), U.S. Bureau of Sport Fisheries and Wildlife (USBSFW), and the State mining, water pollution, and reclamation agencies.

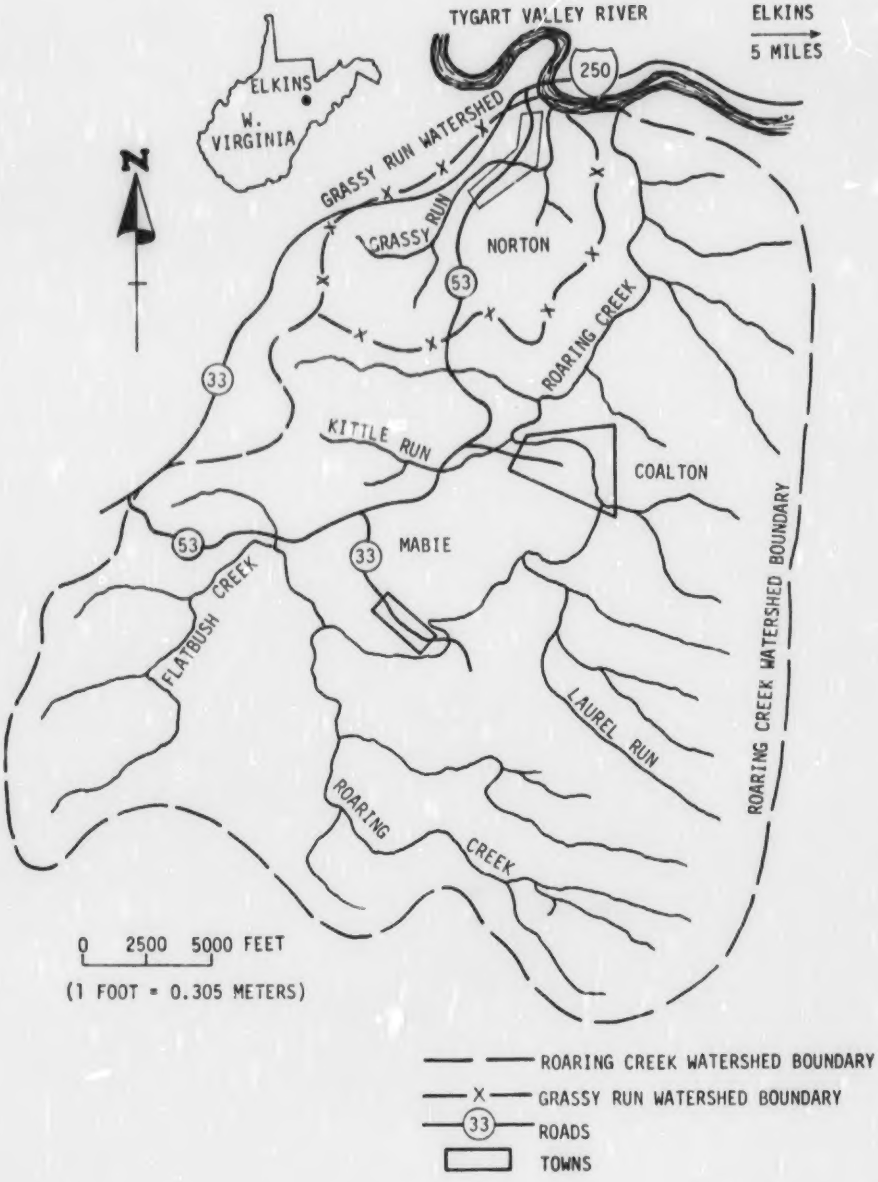
In Fiscal Year 1964, $250,000 was programmed by the Department of Health, Education, and Welfare funds to get the program underway. Fiscal Year 1965 funds of $1,270,000 were divided into three categories: $170,000 for DHEW, $280,000 for the Department of the Interior, and $820,000 for construction contracts.

The Monongahela River Basin of West Virginia was chosen for the first demonstration project because the Monongahela Enforcement Conference that had taken place in 1963 showed acid mine drainage to be a major problem in the basin. At a meeting in Morgantown, West Virginia on February 13, 1964, a Technical Committee was appointed to develop a report on several sites and act as an advisory committee throughout the project. Between February 13 and February 23, 1964, the Committee visited several proposed sites, gathered all available background information, collected water samples for analysis, and prepared a report indicating the advantages and disadvantages of each site. The Committee was instructed not to make recommendations. Streams under consideration were Robinson Run, Dents Run, Scotts Run, Shinns Run, Simpson Creek, Roaring Creek, Grassy Run, Beaver Creek and Laurel Snowy Run. Robinson Run, Scotts Run and Dents Run were eliminated early because the major sources of mine drainage were pump discharges from active shaft mines. The latter four streams were taken under final consideration and on February 27, the report was submitted to DHEW. On March 2, 1964, the Department notified the Technical Committee that the Roaring Creek-Grassy Run area near Elkins, West Virginia, had been selected.

At the May 18, 1964, meeting of the Technical Committee, several objections were raised about the Roaring Creek-Grassy Run site, the major objection being that three mines were currently active in the watershed. A state official, when asked for advice relative to the active mines, estimated that life of the mines was less than a year each. The last of these mines did not close, however, until August 1971, over six years after the estimated closing. This delay made it necessary to adjust some of the initial plans for the demonstration project.

DESCRIPTION OF PROJECT SITE

The study site chosen for the demonstration project (Figure 1) comprises two watersheds near Elkins, West Virginia, draining into the Tygart Valley River in the upper Monongahela and Ohio Basins. The watersheds lie side by side; one, Roaring Creek, covers about 72 square kilometers and the other, Grassy Run, about 10 square kilometers. Both watersheds were included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ROARING CREEK
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KITTLE RUN
COALTON
MABIE
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FLATBUSH CREEK
LAUREL RUN
ROARING CREEK
ROARING CREEK WATERSHED BOUNDARY
0 2500 5000 FEET
(1 FOOT = 0.305 METERS)
ROARING CREEK WATERSHED BOUNDARY
GRASSY RUN WATERSHED BOUNDARY
33
ROADS
TOWNS

Figure 1. Location map of Elkins demonstration project.

because a subsurface network of coal mine passageways and galleries interconnects them and mixes the percolating drainage waters.

Three small towns are located within the watershed, Norton, Coalton, and Mabie. Additionally about two dozen small farms are located along the streams and on the ridges around the rim. Total area under cultivation is not large, but cattle graze over some of the forest area of the watershed. The cover is predominantly hardwood forest, with few openings. The basin has been logged-over several times, but at present only a small amount of timber is cut and that primarily for mine props. One county road and four coal haul roads serve the watershed, and a U.S. highway runs along the northwest rim.

Mining has been the major industry in this area and has created by far the largest impact on the watershed. The first mines opened in the late 1890's and mining continues today. Approximately 1200 hectares have been underground mined and an additional 400 hectares disturbed by surface mines.

Following years of extensive underground and open-pit mining in the Roaring Creek-Grassy Run watersheds, the countryside has become devastated and the flora and fauna of both the terrestrial and aquatic environments have deteriorated significantly. One of the more obvious adverse impacts of mining has been the decline in sport fishing (2). Prior to 1941 a sport fishery for wild brook trout was located in 64.4 kilometers of Roaring Creek and its tributaries. As a result of extensive mining from the 1940's, through the 1960's acid drainage increased continuously in the watershed (see Figure 2). By the mid-1960's (prereclamation) fish life existed in only four limited areas comprising 14.5 kilometers of streams, and sport fishing was all but nonexistent. In addition to destroying fish life in the Roaring Creek and Grassy Run stream system, mining activities in these and other watersheds eliminated sport fishing in 90.0 kilometers of the Tygart Valley River and in part of the 708 hectare Tygart reservoir by the mid 1960's. As a result of mining, biota other than fish have also deteriorated in the aquatic and terrestrial communities of the Roaring Creek-Grassy Run watersheds.

PROJECT OBJECTIVES

The overall objectives of the project were to demonstrate procedures for acid mine drainage control and to evaluate the results and the costs of the work.

The general concept to be demonstrated within the Roaring Creek-Grassy Run watershed was the air sealing of a large underground mine, since the House Committee Print - Acid Mine Drainage had concluded that: "Mine sealing offers the most promising hope in abating acid formation. Water seals are preferable to air seals on abandoned mines when conditions permit complete inundation of the mine. Sealing of abandoned mines and other mine openings, where practical, should reduce the annual acid load by 60 to 70 percent."

Because of the complexity of the mine structures, described in detail later in this report, it was necessary to reclaim surface mines, fill subsidence holes, and remove refuse piles in addition to building mine seals to accomplish air sealing.

CHRONOLOGY OF EVENTS

A chronology is presented in Table 1. What follows is a summary of major events.

Work on the demonstration project was carried out in three phases: (1) site selection, preconstruction evaluation, and reclamation planning; (2) construction of mine seals and regrading and revegetation of surface mines; and (3) project evaluation. Phase 1, begun in March 1964 and completed in July 1966, was devoted to water quality surveillance (EPA); stream gaging (USGS); surface mapping, investigation of mine conditions, and designing control measures and reclamation planning (USBM); securing land permits (W. Va.); and awarding the construction contract (EPA, USBM). Sealing of the mines and concurrent reclamation measures (Phase 2) were begun in July 1966 and terminated in September 1967. Disturbed areas were revegetated in the spring of 1968. Phase 3, evaluation of the effectiveness of mine sealing and reclamation measures, is continuing.

TABLE 1. CHRONOLOGY OF EVENTS

1962:	The Committee on Public Works, House of Representatives, in House Report No. 306 (87th Congress, 1st Session) requested the Secretary of Health, Education, and Welfare to undertake a study of water pollution caused by acid mine drainage.
April 1962:	The Division of Water Supply and Pollution Control, Department of Health, Education, and Welfare submitted their report on the effect of acid mine drainage to the 2nd Session of the 87th Congress.
Fiscal year 1964:	$250,000 was programmed from the Deparment of Health, Education and Welfare to get the acid mine drainage program underway.
February 13, 1964:	A Technical Committee was appointed to develop a report on several potential study sites and act as an advisory committee throughout the project.
February 13 to 20, 1964:	The Technical Committee visited a number of prospective sites and gathered background information.
February 27, 1964:	The Technical Committee submitted their findings on the prospective sites to the Department of Health, Education and Welfare.
March 2, 1964:	The Department of Health, Education and Welfare notified the Technical Committee that the Roaring Creek-Grassy Run watersheds had been selected for the project site.
Fiscal year 1965:	$1,270,000 was alloted to the project. The funds were divided among the cooperating agencies.
January 1965:	The U.S. Bureau of Mines prepared a report entitled "Mining Inventory and Preliminary Guide to Reclamation on Roaring Creek and Grassy Run Watersheds". This report was the basis for the reclamation program.
January 18, 1966:	"Request for proposal" was submitted to firms for the reclamation work. Eleven bids were received.
June 30, 1966:	The reclamation contract was awarded to Franklin W. Peters and Associates for $1,640,383.
July 1966:	Reclamation work began.
August 10, 1967:	The FWPCA made the decision to terminate work.
September 15, 1967:	A modified reclamation plan was developed.
November 17, 1967:	The modified project was inspected and accepted by the Government.
October 10, 1967:	The revegetation project was started by the Tygarts Valley Conservation District.
July 1968:	The revegetation project was completed.
January 1972:	All regular sampling at the project site was concluded.

SECTION 4

PRELIMINARY DETERMINATION OF CONDITIONS AT THE PROJECT SITE

Preliminary investigations and evaluations of the project area were carried out in order to:

- Provide detailed data to establish characteristics of the site,
- Determine control measures that could be applied,
- Prepare specifications and design for the construction and installation of control measures, and
- Produce baseline data which could be compared to post-reclamation data so the success of the project could be evaluated.

The development of necessary information involved mapping of the project site, delineation of past and present mining operations, and geologic and hydrologic investigations. The initial work also included securing permits to work on private land in the project area.

The preliminary evaluations and investigations were carried out by the various agencies involved in the demonstration project:

1. EPA - Program supervision and direction, water quality surveillance, cost accounting, and biological studies of bottom fauna, algae, and plankton.
2. USGS - Stream gaging, mapping ecological structure and groundwater movement, and survey of groundwater quality.
3. USBM - Surface mapping, inventorying mine conditions, drilling programs, and engineering design of control installations.

4. USBSFW - Inventorying fish populations before and after control measures and studying fish in any impoundments developed in the program.

5. State Agencies - Determining land ownership, securing permits for access to property, and providing local publicity.

6. EPA and USBM - Arranging work contracts, and inspecting and accepting installed control procedures.

7. All agencies - Share in selecting sites and proposing pollution control measures.

Since a number of agencies were involved in the project, the tasks listed above were, for the most part, carried out simultaneously.

MINING OPERATIONS WITHIN THE PROJECT SITE

A history of mining operations in the area was developed by reviewing past records and literature and by interviewing local officials and citizens.

Underground Mining

Early records indicate that the West Virginia Coal and Coke Company was probably the first company to mine in the watershed, starting an underground mine in 1895 at Coalton in the Kittanning coal seam (Figure 3). Later the same firm opened a drift mine at Norton. Other drift mines were operated over the years by small independent coal mine operators in the southerly section of the coal field in the vicinity of Coalton and Mabie. By 1940, the Norton mine had advanced south and intercepted the old Coalton mine, forming a massive underground mine complex of approximately 1214 hectares, not including a number of smaller underground mines in the watershed, (Figure 3). One company operated in the complex near Norton until August 1971. During the last several years of operation it was primarily involved in pulling pillars near the pit mouth.

The Kittanning coal seam dips to the north and also to the west and lies above surface drainage; therefore, drift mouth openings at Norton and Coalton were located on the downdip side of the coal seam to realize the economic benefits of hauling coal downgrade and to allow natural drainage from the mine. A double entry system of mining was incorporated by driving headings updip from the drift mouth and then driving the cross or butt entries at right angles on each side of the main heading. Generally, rooms were turned at right angles to the butt headings at a predetermined distance apart, the distance between the center-lines of adjacent rooms being equal to the width of the

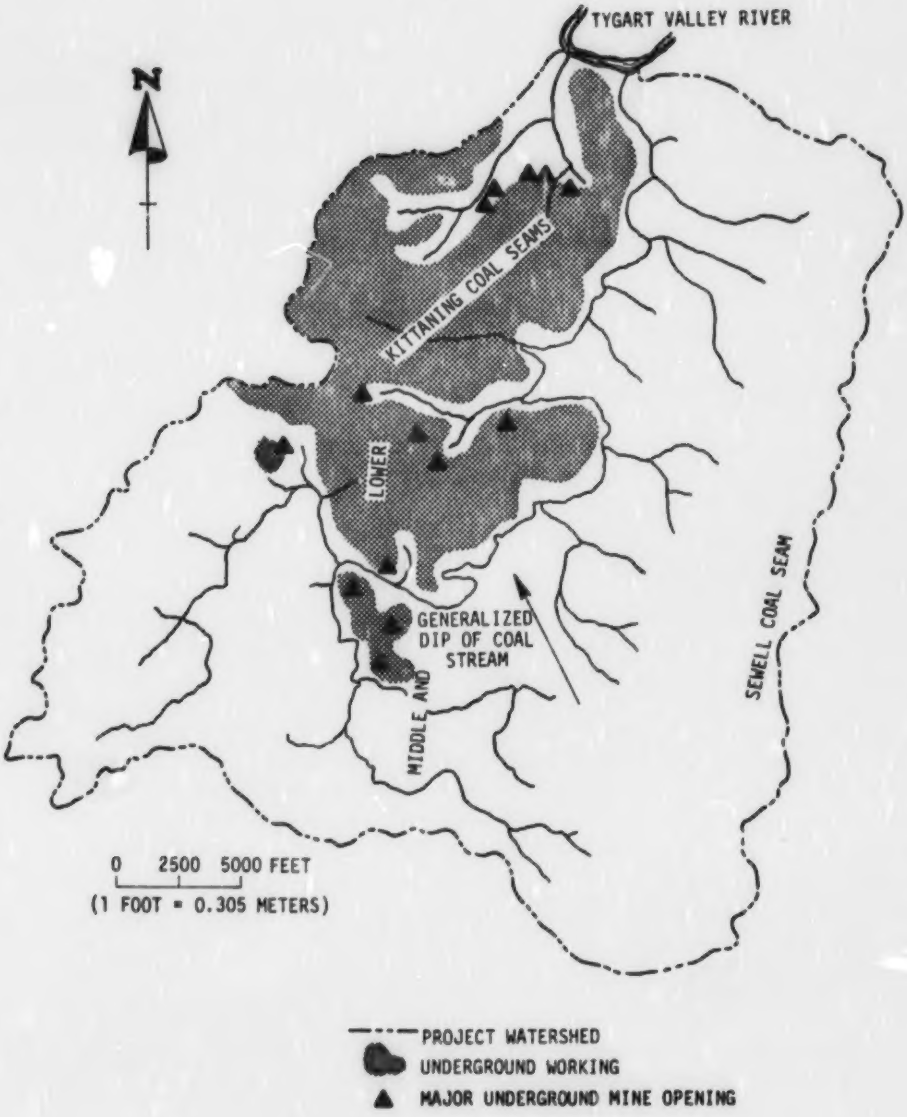

TYGART VALLEY RIVER
N
KITTANING COAL SEAMS
LOWER
MIDDLE AND
GENERALIZED DIP OF COAL STREAM
SEWELL COAL SEAM
0 2500 5000 FEET
(1 FOOT = 0.305 METERS)
PROJECT WATERSHED
UNDERGROUND WORKING
MAJOR UNDERGROUND MINE OPENING

Figure 3. Underground mine working.

room added to the thickness of the pillar between the rooms. These rooms were driven perpendicular to the butt headings so as to eventually interconnect.

The advance and retreat system was used on the butt entries. The advance into the seam was made by driving several adjacent rooms a predetermined distance at right angles to the butt headings. Immediately after the rooms were driven, retreat was made from the rooms by extracting the pillars on a 45 degree angle. A 24-meter barrier pillar was left standing by the main air course heading as a protective measure. Coal was extracted by using an arcwall cutting machine, which cut overhead into solid coal approximately 2.7 meters deep and 5.4 to 6.0 meters wide: then the miner drilled the block of coal with a hand auger and shot the coal with dynamite. The coal was hand-loaded into mine cars and transferred by gathering motors to the main heading, where the mine cars were pulled to the tipple outside by a mainline motor.

During the period 1920-1924 mechanized mining (long wall) was used at the Norton mine, one of the first mechanized mines in the world. The long wall method utilized top machine cutters and steel conveyors to mine and transfer coal to an outside tipple or to a place where it was loaded into mine cars and transferred by electric motor to the outside. The system of mining did not prove to be economically feasible because excessive man hours were required to move the cumbersome equipment from one section of the mine to another. Mechanized mining was therefore discontinued in 1924. It is estimated that 65 to 70 percent of the Kittanning coal in the watershed has been recovered by the two mining methods just described.

Strip Mining

At the beginning of World War II (1942), contour strip mining began at Norton. By 1950 almost all the outcrop encompassing the deep mines had been extensively surface mined, resulting in more than 400 hectares of disturbed land in the watershed (Figure 4).

Surface mining was accomplished by contour stripping the coal at the outcrop. This method consisted of removing the overburden from the mineral seam and following the outcrop around the hill. The overburden was deposited along the outer edge of the bench or pushed down the hillside. The spoil pile often served as a dam, preventing water from leaving the pit and directing it toward the highwall and the underground mine behind (Figure 5). Surface mining intercepted the underground mines in numerous places, diverting water directly into them (Figure 6).

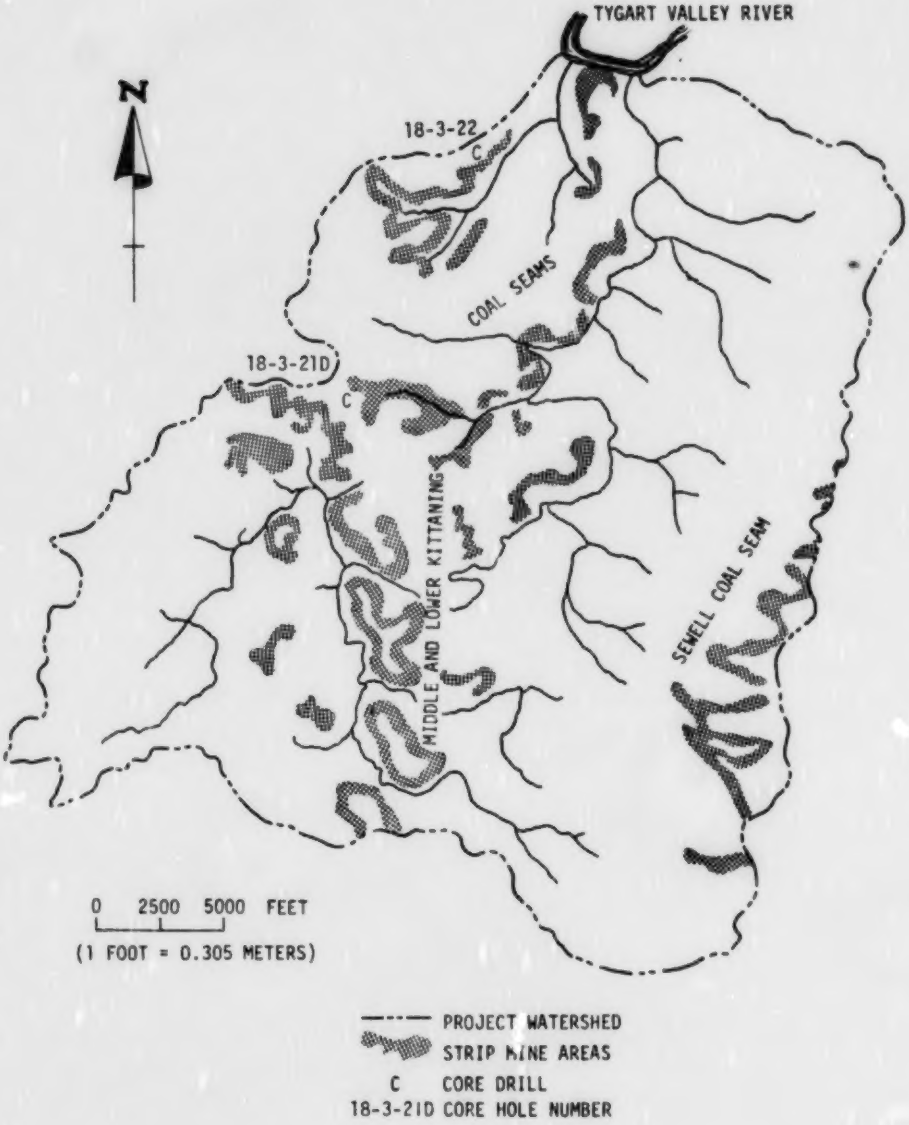

TYGART VALLEY RIVER
N
18-3-22
C
COAL SEAMS
18-3-21D
C
MIDDLE AND LOWER KITTANING
SEWELL COAL SEAM
0 2500 5000 FEET
(1 FOOT = 0.305 METERS)
PROJECT WATERSHED
STRIP MINE AREAS
C CORE DRILL
18-3-21D CORE HOLE NUMBER

Figure 4. Surface mine working.

Figure 5. Abandoned underground mine opening - Roaring Creek, Site RT5-2.

Figure 6. Abandoned strip mine - Kittle Run.

Because it was not required by mine laws during the period of strip mining, little or no surface mine reclamation was performed. Some locust seed was broadcast over a portion of the strip mined area early in the 1950's. The limited vegetative cover was volunteer growth consisting mostly of locust, wild cherry, and aspen.

Quantity of Coal Mined

Total coal production for the watershed is not known. Maximum annual production for the Coalton workings was 490,244 metric tons in 1942. The total amount of coal mined from the entire complex (Coalton mine) can be estimated by assuming 1) 1200 hectares mined, 2) 70 percent extraction and 3) a 1.37-meter seam. Based on these assumptions an estimated 13,475,000 metric tons were mined.

RECONNAISSANCE OF THE PROJECT AREA

The first field effort of the study involved detailed reconnaissance of the project area by the cooperating agencies to locate all openings where air and water could enter the subsurface mine workings. Personnel of the USBM and EPA began the survey by inspecting aerial photos and old mine maps. Later they covered the watershed on foot to find any openings not referenced on the maps and to identify fissures (subsidence areas) created by settling of overlying rock when coal was removed. The survey revealed several mine seals built more than 30 years before during a WPA project. Some 625 openings and several thousand subsidence holes were identified.

GEOLOGY

Geology of the Roaring Creek-Grassy Run area was mapped by the U.S. Geological Survey in 1967, and two reports have been prepared. Englund, in 1967, prepared an administrative report for the Water Resources Division, USGS (5). Gallaher prepared a more detailed report in 1971 (6). These reports are summarized in the following paragraphs.

Methods of Evaluation

Geological features were plotted, with the aid of aerial photographs, on topographic base maps at a scale of 1:40,800. Altitudes of contacts and coal beds were determined by hand leveling or by aneroid barometer traverses, with readings corrected for temperature and atmospheric variations. Exposed stratigraphic sections were studied in road cuts and in the highwalls of strip mines, and subsurface data were determined from analysis of core samples. The core drilling program was carried out by the Bureau of Mines and the Geological Survey. The data provided information on both the geology and groundwater hydrology of the project area. Figure 7 depicts the locations where core drilling took place. Exposures of coal at mine openings, strip mines, prospects, and roadcuts were analyzed and additional data relating to coal were obtained from mine maps and core drill records. In compilation of the structure contour map, and geologic map, field data were transferred to a 1:12,000 scale topographic base map. The field work was facilitated by the cooperating agencies, who furnished logs of drill holes (core holes or bore holes), mine maps, and coal analyses.

Topography

The Roaring Creek-Grassy Run area includes the drainage basins of Roaring Creek and Grassy Run in northwest Randolph County, West Virginia (Figure 1). Both streams flow northward into the Tygart Valley River and together drain an area of about 82 square kilometers. From the Tygart Valley River, the Roaring Creek-Grassy Run area extends 11.2 kilometers to the south and is bounded on the east by the crest of Rich Mountain and on the west by the divide on the west side of Grassy Run. Outline of the area is irregular, ranging from 7.8 kilometers wide at the Tygart Valley River to 9.6 kilometers wide across the headwaters of Roaring Creek.

The Roaring Creek area is situated near the east edge of the Appalachian Plateaus (Figure 1) and is physiographically divisible into two areas (Kanawha and Allegheny sections), each closely related to the weathering characteristics and structure of the underlying rocks. The Kanawha section comprises the western two-thirds of the area. This section has gently dipping beds of relatively nonresistant shale, siltstone, sandstone, coal and underclay and exhibits maturely dissected topography and dendritic drainage patterns. Most of the streams occupy narrow V-shaped valleys that lie between broad flat uplands supported by moderately resistant sandstone beds. Topography in the eastern third of the area, from the base to the crest of Rich Mountain, is typical of the Allegheny section of the Appalachian Plateaus. On the west slope of the mountain, tributaries of Roaring Creek downdip between cliffs and flatiron-like ridges carved from moderately dipping sandstone and conglomeritic sandstone. Altitudes range from a minimum of 564.6 meters along Tygart Valley River to a maximum of 1116.9 meters at the crest of Rich Mountain.

Physical Geology

The Roaring Creek-Grassy Run watersheds lie in the broad Belington syncline, which is centrally located in the Appalachian geosyncline between relatively flat-lying rocks to the west and more intensely folded rocks to the east. The trough line of the syncline strikes irregularly northward across the project area and plunges about 19 meters per kilometer in that

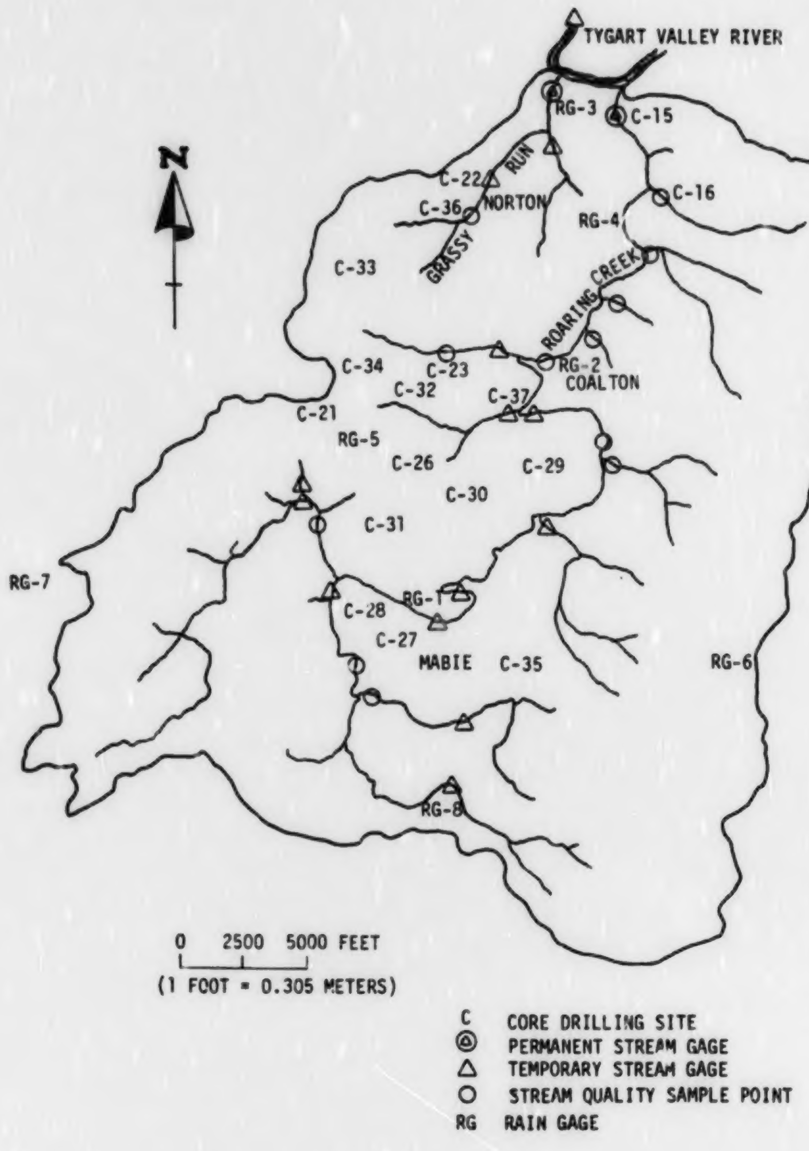

TYGART VALLEY RIVER
N
RG-3
C-15
C-22
GRASSY RUN
NORTON
C-36
C-16
RG-4
C-33
ROARING CREEK
C-34
C-23
RG-2
COALTON
C-32
C-37
C-21
RG-5
C-26
C-29
C-30
C-31
RG-7
RG-1
C-28
C-27
MABIE
C-35
RG-6
RG-8
0 2500 5000 FEET
(1 FOOT = 0.305 METERS)
C CORE DRILLING SITE
◎ PERMANENT STREAM GAGE
△ TEMPORARY STREAM GAGE
○ STREAM QUALITY SAMPLE POINT
RG RAIN GAGE

Figure 7. Core drilling sites, gaging stations and water quality points.

direction. In the western two-thirds of the area, which includes the trough and west limb of the syncline, the rocks are gently dipping as shown by structure contour lines drawn at the base of the Kittanning coal bed and a correlative horizon. On the west limb, the dip of the beds is generally less than 3 degrees, ranging mostly from 19 to 47.5 meters per kilometer. Anomalies include several small anticlines and synclines, in strip mines at the head of Grassy Run, that strike N. 45°E. and have an amplitude of less than 3 meters. The west limb also includes a shallow syncline that strikes N. 30° E. 30° E. from the head of Kittle Run to Grassy Run and merges with the Belington syncline at Norton.

About 671 meters of sedimentary rocks of late Mississippian to late Pennsylvanian age crop out in the Roaring Creek area. Of this total, the basal 250 to 267 meters of the beds are mostly marine rocks that are assigned to the Greenbrier and Mauch Chunk formations of late Mississippian age. Outcrops of these formations are limited to a few localities on the east edge of the area. The remainder of the stratigraphic sections consist largely of continental coal-bearing rocks of the New River, Kanawha, Allegheny, and Conemaugh formations of early to late Pennsylvanian age. These formations are at the surface in nearly all of the study area but are locally covered by deposits of Quaternary age.

The Allegheny formation of middle and late Pennsylvania age is a coal-bearing sequence of sandstone, siltstone, and shale that lies between the Kanawha and Conemaugh formations in West Virginia. In the Roaring Creek area, it ranges from 81 to 92 meters thick. This formation includes a persistent clay bed at its base, two economically important coal beds -- the Clarion and Kittanning -- and a mapped sandstone member near its top. The formation outcrops in nearly all of the area west of the foot of Rich Mountain.

The Kittanning coal bed, the most widely mined coal in the Roaring Creek area, has been nearly depleted by extensive underground and strip mining. The bed has a maximum thickness of about 3 meters, excluding partings, near Coalton in the trough of the Belington syncline. Westward on the limb of the syncline the bed is split into three benches by underclay and carbonaceous shale partings as much as 0.6 meter thick. Only black carbonaceous shale and underclay were found at the position of the Kittanning coal bed in the ridge that fringes the southwest edge of the area. The Kittanning coal bed is composed mostly of bright attritus with minor amounts of vitrain and dull attritus. Lenses of pyrite and pyritic impure coal as much as 7.6 cm thick are common in the bed.

The strata between the Kittanning coal bed and a mapped sandstone member in the upper part of the Allegheny formation range from 26 to 38 meters in thickness and consist mainly of medium-gray shale and silty shale (Figure 8). This part of the formation also includes lenticular beds of fine- to coarse-grained sandstone, siltstone, coal, underclay, and argillaceous limestone. A persistent bed of canneloid shale, as much as 46 cm thick, occurs 0.6 to 0.9 meter above the Kittanning coal bed.

Analysis of Coal Mined in the Area

The upper, middle, and lower Kittanning coal seams are found in the project area. Since the coal rises to the south and east, the upper and middle Kittanning seam eventually pinches out in the upper reaches of the Roaring Creek-Grassy Run watershed.

Analyses indicate that Kittanning coal is of high-volatile A-bituminous rank, with moderate to high sulfur and ash contents. Results of sampling of the coal profile at two locations in the Norton mine are presented in Table 2. A geological cross section appears in Figure 8. Total thickness of the bed sections ranged from 2.25 to 2.5 meters. The floor was clay and the roof slate. Ash content ranged from 9.4 to 11.7 percent and sulfur content from 0.6 to 0.8 percent, considered a low sulfur coal.

Seven additional samples were collected by the Bureau of Mines in various work areas in early 1965. The analyses are shown in Table 3.

Sewell coal is located at higher elevations on the east side of the watershed. Analysis of Sewell coal is given in Table 4. Sewell coal is a high-grade coal desirable for metallurgical uses. It constitutes less of a pollution problem than Kittanning coal which is more desirable as a steam or utility fuel.

Logs of two cores recovered from drilled test holes are shown in Figures 9 and 10. Locations of the test holes are shown in Figure 7. These cores indicate the physical and chemical properties of the overburden. Samples from core 18-3-22 (Figure 9) revealed above the coal at a depth of 16.3 meters a layer of material having a high pyritic content (9.96 percent). This layer is probably a major source of acid mine drainage. Core 18-3-21D (Figure 10) also had a high pyritic content in the overburden above the coal. Thus both cores indicate that the overburden material contains considerably more acid-bearing pyrite sulfur than does the Kittanning coal seam and thus is probably the major source of the acid mine drainage.

TABLE 3. COAL ANALYSIS[a]

Work Area No.[b]	Proximate Analysis				Ultimate Analysis					
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Ash
44 (Fisher Strip)	2.9	28.0	56.3	12.8	4.8	72.3	1.5	7.9	0.7	12.8
6 (Flat Bush #3)	2.3	30.2	55.0	12.5	5.0	74.1	1.5	5.8	1.1	12.5
10 (Proud Foot)	2.6	28.8	53.5	15.1	4.8	69.9	1.4	6.4	2.4	15.1
39 (Norton #1)	2.4	30.2	57.7	9.7	5.1	76.6	1.5	6.3	0.8	9.7
21 (Sylvester)	3.5	28.8	56.5	11.2	5.0	73.6	1.5	7.6	1.1	11.2
33 (Norton #2)	3.1	27.2	58.4	11.3	4.9	73.8	1.4	7.8	0.8	11.3
36 (Norton #2)	10.8	25.0	54.8	9.4	4.9	65.4	1.3	18.4	0.6	9.4

FORMS OF SULPHUR:	Sulfate	Pyritic	Organic
As received	.04	.41	.58
Moisture free	.04	.43	.61
Moisture & ash free	.05	.50	.69

[a] Samples collected and analyzed by U.S. Bureau of Mines.
All of above analyses are as - received.
Coal: upper, middle and lower Kittanning

[b] See Figure 21 for location of work areas.

TABLE 4. PROXIMATE ANALYSES OF SEWELL SEAM - RICH MOUNTAIN NEAR ELKINS, WEST VIRGINIA

	Low	High
Moisture, %	0.90	1.26
Volatile matter, %	28.10	30.99
Fixed carbon, %	63.07	67.03
Ash, %	2.87	6.00
Sulfur, %	0.48	0.59
Calorific value, Btu	14,237	14,875

HYDROLOGY OF THE PROJECT SITE

Climate

The climate of the project area is of the continental mountainous type, with relatively cold winters and mild summers. Long-term temperature averages at the Elkins Airport, altitude 599 meters, range from a monthly normal of 0.3°C in January to 21.1°C in July, with an annual average normal of 10.4°C. These figures represent the conditions in the valley bottom, but daily temperatures in higher regions (i.e., Rich Mountain) are about 6 to 8 degrees lower throughout the year.

Precipitation received by the basin is derived from moisture-laden air from three main sources: (1) the southwesterly flow of air from the Gulf of Mexico, (2) the easterly flow from storms traveling up the Atlantic Coast, and (3) the northwesterly flow of air that picks up moisture over the Hudson Bay-Great Lakes region and generates frequent snow showers during winter. Although intense thunderstorms cause local flooding during the summer, basin-wide flooding occurs more frequently in early spring as a result of general large-scale storms. Surface runoff from these storms is sometimes intensified by snowmelt. The Elkins long-term annual precipitation average is 1.19 meters.

There are four weather stations within a few miles of the project area, but the climatological conditions at those stations vary considerably from those within the area of study. Therefore, as a means of determining the seasonal and areal distribution of precipitation within the project area, a network of precipitation stations was established (Figure 7).

Rain Gages 1 and 2 (RG-1 and 2), in Mabie and Coalton respectively, were installed in February 1965. To indicate any variations in precipitation caused by topographic or geographic

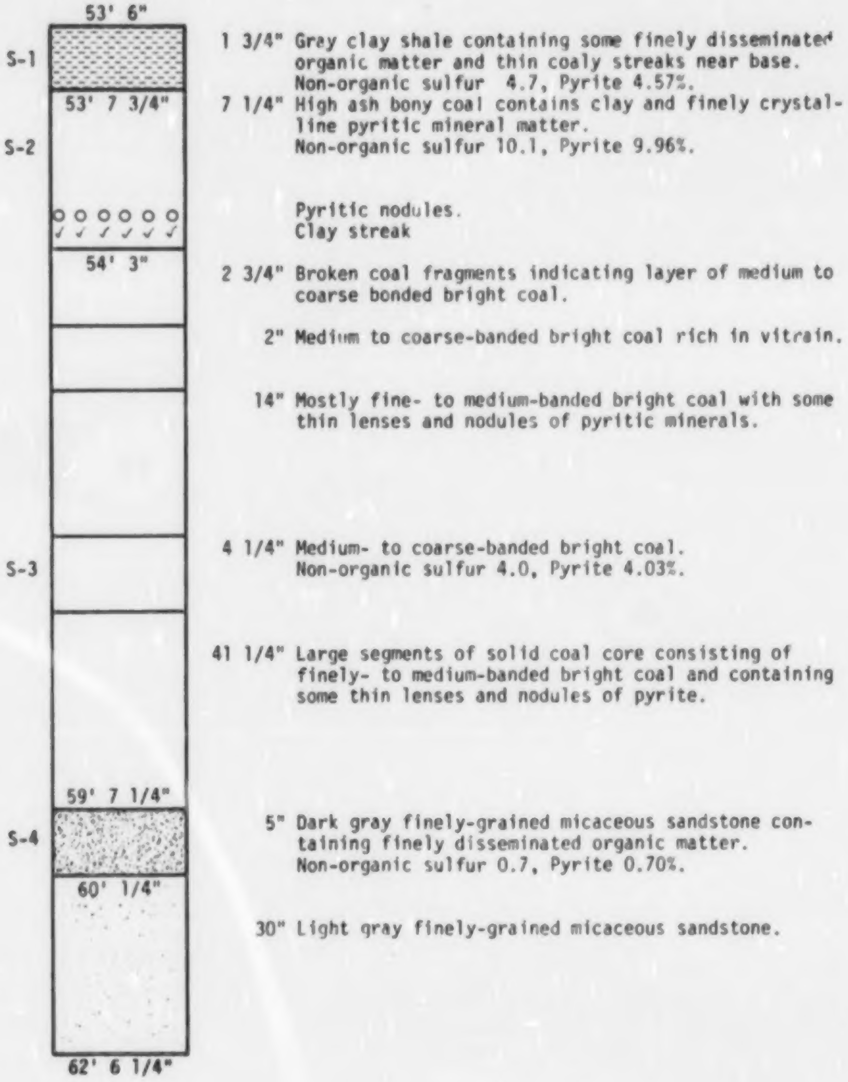
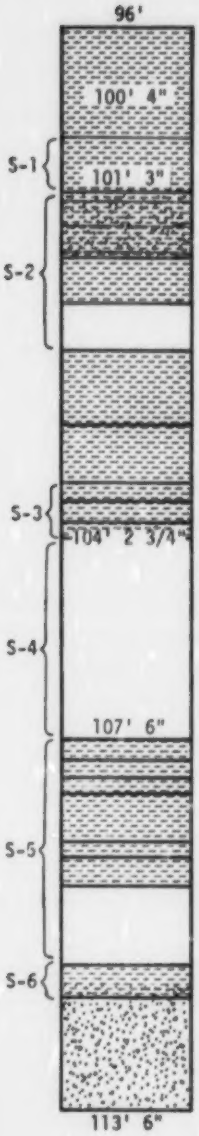

53' 6"
S-1
1 3/4" Gray clay shale containing some finely disseminated organic matter and thin coaly streaks near base. Non-organic sulfur 4.7, Pyrite 4.57%.
53' 7 3/4"
S-2
7 1/4" High ash bony coal contains clay and finely crystalline pyritic mineral matter. Non-organic sulfur 10.1, Pyrite 9.96%.
Pyritic nodules.
Clay streak
54' 3"
2 3/4" Broken coal fragments indicating layer of medium to coarse bonded bright coal.
2" Medium to coarse-banded bright coal rich in vitrain.
14" Mostly fine- to medium-banded bright coal with some thin lenses and nodules of pyritic minerals.
S-3
4 1/4" Medium- to coarse-banded bright coal. Non-organic sulfur 4.0, Pyrite 4.03%.
41 1/4" Large segments of solid coal core consisting of finely- to medium-banded bright coal and containing some thin lenses and nodules of pyrite.
59' 7 1/4"
S-4
5" Dark gray finely-grained micaceous sandstone containing finely disseminated organic matter. Non-organic sulfur 0.7, Pyrite 0.70%.
60' 1/4"
30" Light gray finely-grained micaceous sandstone.
62' 6 1/4"

Figure 9. Diagram of drill core sample No. 18-3-22 (Interval 53 feet 6 inches to 62 feet 6 inches).[a]

[a] To convert inches to centimeters multiply by 2.54; to convert feet to meters multiply by 0.305.



63"	Massive bedded varied layers of light and dark gray silty clay
5 1/2"	Interlaminated layers of silty clay, sand, and coal containing thin lenses of finely crystalline pyritic mineral matter. Non-organic sulfur 0.1, Pyrite 0.06%.
5 1/4"	Dark gray silty clay shale containing finely disseminated organic matter. Non-organic sulfur 6.7, Pyrite 6.69%.
2 1/4"	Finely banded bright coal with thin streaks pyritic mineral matter.
9"	Dary gray silty clay shale containing finely disseminated organic matter.
6 1/2"	Dark gray silty clay shale with finely disseminated organic matter.
7 1/4"	Black carbonaceous silty clay shale with thin coal streaks. Non-organic sulfur 1.0, Pyrite 0.93%.
5 1/2"	Solid coal core representing finely- to medium-banded bright coal and containing thin partings of silty clay and thin lenses of pyritic mineral matter.
33 3/4"	Broken coal core, coal fragments indicate a finely- to medium-banded bright coal containing silt and clay mineral impurities. Non-organic sulfur 2.5, Pyrite 1.87%.
2 3/4"	Interbanded coal and silty clay layers.
4 1/4"	Gray silty clay shale with finely-disseminated organic matter.
4 1/2"	Dark gray silty clay shale with thin coal streaks.
2"	Finely- to medium-banded bright coal with thin pyrite streaks and thin films of sulfate mineral matter - selenite - calcium sulfate on bedding planes. Non-organic sulfur 2.1, Pyrite 1.77%.
8"	Gray silty clay shale with increasing amount of sand and mica in lower portion.
27 1/2"	Fine grained, gray, micaceous sandstone containing some finely-disseminated organic matter. Non-organic sulfur 0.2, Pyrite 0.21%.

Figure 10. Diagram of drill core sample No. 18-3-21D (Interval 96 feet to 113 feet 6 inches).[a]

[a] To convert inches to centimeters multiply by 2.54; to convert feet to meters multiply by 0.305.

location, six additional gages were later installed throughout the area. Except for RG-6 on Rich Mountain, all gages were read daily by observers. RG-6, the last to be installed (January 1967), was a recording rain gage. Table 5 briefly describes the precipitation gages. Precipitation data obtained from each rain gage are also contained in the Appendices.

Gages RG-1, 2, and 4 were used to determine precipitation for Roaring Creek drainage area and rain gage RG-3 was used for the Grassy Run watershed. Only partial records were available at other sites as operation of some gages was discontinued in September 1967.

Analysis of conditions within specific portions of the project area, required development of detailed precipitation data. Estimates for periods of missing records were based on coefficients determined by comparing available records with Weather Bureau records at Elkins, West Virginia. Missing data for gages RG-1 and RG-2 were calculated by multiplying the Elkins values by a coefficient of 1.2. Similarly, data for RG-3 and RG-5 were based on coefficients of 1.10 and 1.07, respectively.

As shown in Table 6, the greatest precipitation was recorded at lower altitudes, as at Mabie (RG-1) and Coalton (RG-2). This is probably related to release of moisture from air moving across the high elevation of Rich Mountain. Also, more precipitation fell at Norton (RG-3) than at the higher elevation in the vicinity of Kittle Run. Generally, maximum precipitation occurred during the second quarter.

Surface Water

As already indicated, the project area is drained by two main streams discharging into the Tygart Valley River. The smaller of these streams, Grassy Run, drains the northwest portion of the project area and Roaring Creek drains the remainder. The main streams of Grassy Run and Roaring Creek are, respectively, 4.5 kilometers and 20 kilometers long. Courses of these streams and their major tributaries are shown in Figure 7.

Monitoring Points and Sampling Stations--

Monitoring stations were established throughout the watershed (Figure 7) to determine water quality and quantity. The letter-and-number designation system for the monitoring sites evolved according to the needs of the project. G, R, and T refer to Grassy Run, Roaring Creek, and tributary streams, respectively. Sites on the main stems of the streams are assigned a single letter; those on tributaries have the letter T affixed. The RM prefix used near the old Mabie mine, work area

TABLE 5. DESCRIPTION OF PRECIPITATION MONITORING

Gage (RG)	Date of Installation	Location	Altitude (above msl),[a] feet[b]	Months of record
1	Feb. 9, 1965	Mabie, W. Va.	2240	83
2	Feb. 10, 1965	Coalton, W. Va.	2150	71
3	Apr. 27, 1966	Norton, W. Va.	1940	31
4	May 25, 1966	On Roaring Creek East of Norton, W. Va.	2140	18
5	Apr. 30, 1966	Upper Kittle Run near Mabie, W. Va.	2335	68
6	Jan. 13, 1967	Rich Mountain	3235	11
7	Sep. 2, 1966	Pumpkintown	2515	15
8	May 25, 1966	Above Mabie, W. Va.	2475	18
Elkins W B Airport	Daily Records	nr. Elkins, W. Va.	1970	73[c]

[a] msl - mean seal level.

[b] To convert feet to meters multiply by 0.305.

[c] Years - Established 1899.

TABLE 6. QUARTERLY PRECIPITATION DATA (INCHES)[a]

Year	Station/Quarter	Mabie (RG-1)	Coalton (RG-2)	Norton (RG-3)
1965	1	12.72	12.43	
	2	11.65	11.20	
	3	8.95	9.37	
	4	6.68	6.47	
	Total Annual	40.00	39.47	
1966	1	10.42	9.97	8.03
	2	12.14	11.57	10.76
	3	15.06	15.85	13.75
	4	9.01	8.72	9.05
	Total Annual	46.63	46.11	41.59
1967	1	13.79	14.23	13.56
	2	16.74	15.59	15.95
	3	16.22	15.26	14.04
	4	11.43	12.16	11.04
	Total Annual	58.00	57.24	54.95
1968	1	8.73	8.74	
	2	12.69	12.26	
	3	11.54	11.36	
	4	12.15	12.06	
	Total Annual	45.11	44.92	

[a] To convert inches to centimeters multiply by 2.54.

31*, is a later designation indicating mine drainage monitoring sites in that area. The numerical portions of the designations vary in meaning and use. On the main stems the monitoring sites are simply numbered sequentially in upstream order. The tributaries are also numbered in upstream order, and a two-part number is generally used to describe sites in their basins. The first part is common to sites within a given tributary basin. For example, those designated RT-6 are all within Kittle Run, the sixth numbered tributary from the mouth of Roaring Creek. Some sites in the southern part of the deep mine area are given an additional letter, as RT8G-; these designations describe sites in subtributary watersheds. The final number is part of an upstream sequential system used to describe specific sites within the tributary drainage system. Letters accompanying the final number generally designate monitoring stations that were added either to replace older stations performing the same function or to provide additional data. A description of the various stations sampled is presented in Table 7.

Stream Flow--

In 1964, personnel of the U.S. Geological Survey established a surface water monitoring network as a means of determining the volume of water moving past certain points within the project area, both at regular intervals and during periods of unusually high or low discharge. The density and areal coverage of the initial network were based on the premise that complete restoration of the mined areas would be accomplished. About 140 stations were established and monitored. These included two permanent gage houses constructed near the mouths of Roaring Creek and Grassy Run, and less elaborate sites at the mouths of tributary streams and at mine drains. In October 1967, two continuous recording gage sites were established at the mouth of Kittle Run (RT6-1) and on Flat Bush Run (RT9-2). Additionally, many sites were selected for instantaneous measurement of flows and seepage during high streamflow conditions. Water samples for quality analysis usually were collected at the time of the discharge measurements.

During the course of the project, changes were made in the monitoring sites, based on their suitability for meeting specific needs. As reclamation work began, some measuring stations were discontinued or shifted to nearby sites, and some were added to the network.

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* The project site was divided into a number of work areas so that specific locations could be easily identified. Although these work areas were developed principally for the reclamation project, they are cited throughout the report for convenience. (See Figure 21 for location).

TABLE 7. LOCATION AND DESCRIPTION OF WATER MONITORING SITES[a]

Sample site	Purpose
G-1	Mouth of Grassy Run - monitoring overall effectiveness of reclamation work on Grassy Run
G-2A	Measure influence of reclamation work in Area 10 on Grassy Run
G-3	Same as G-2A
GT1-9	Same as G-2A
GT6-1	Same as G-2A
R-1	Mouth of Roaring Creek - monitor overall effectiveness of reclamation
R-2A	Influence of reclamation on Roaring Creek
R-3	Influence of Areas 11 and 44 when used with R-5 Influence of Areas 10, 12 - 20 when used with R-2A
R-5	See R-3
R-6	Influence of Areas 23 - 24, 1 - 9, and 27 - 30 when used with R-7
R-7	See R-6
R-8	Low level of pollution above most mining
RT5-1	Influence of diversion in Area 10
RT5-2	Mine sealing effectiveness in Area 22
RT6-1	Influence of diversion in Areas 10, 13, 15 - 20
RT6-2	Influence of Area 12
RT6-2A	Wet seal Area 12
RT6-3	Wet seal Area 12
RT6-5	Wet seal Area 13
RT6-6A	Wet seal Area 14
RT6-9	Wet seal Area 10

(continued)

TABLE 7 (continued).

Sample site	Purpose
RT6-12	Wet seal Area 18
RT6-19	Wet seal Area 20
RT6-20	Influence of Areas 13 - 18
RT6-21	Mouth of Area 10
RT6-23	Wet seal Area 10
RT6-25	Area 10
RT6-26	Wet seal Area 10 - shaft to main drainway
RT6A-1	Wet seal Area 53
RT8B-1	Influence of Area 44
RT8B-2	Wet seal (near) Area 44
RT8F-1	Influence of Areas 28 - 30
RT8F-5	Wet seal Area 28
RT9-2	Influence of Area 1 - 9 and 23 - 24
RT9-3	Non-polluted water
RT9-11	Wet seal Areas 23 - 24
RT9-23	Influence of Areas 1 - 9, 23 - 24, and 27
T-1	Above influence of Roaring Creek-Grassy Run
T-2	Influence of Roaring Creek-Grassy Run
RT6-6	Surface runoff Area 17
RT6-12S	Surface runoff Area 18
RT9-6	Surface runoff Area 3
RT9-7	Surface runoff Area 2
RT9-8	Surface runoff Area 1
RT9-9	Surface runoff Area 7
RT9-9S	Surface runoff Area 6

[a] See Figure 21 for location.

Frequency of streamflow measurements at selected sites varied considerably. Most of the water-stage measurements at the two permanent stream gages were made by continuous recording strip charts or by an automatic punch-tape device; periodic supplementary discharge-rating measurements were made by USGS or EPA personnel. These data are available from the USGS (7). At 25 to 30 other critical sites, discharge measurements were made weekly and at times of unusually high or low flow. At the balance of the sites, discharge was measured monthly, seasonally, or randomly, depending upon their purpose in the network. In August 1968, discharge measurements and water quality sampling were reduced to a bi-monthly schedule; after July 1971, the operations were further reduced to a monthly schedule.

In October 1967 all construction work on the project was terminated (except for revegetation). Since all work performed by cooperating agencies was completed, EPA personnel monitored the streams until January 1, 1972, at which time these follow-up studies were concluded.

Runoff and Evapotranspiration--

Mean precipitation for Roaring Creek watershed was computed by averaging monthly records for RG-1, 2, and 5. Precipitation for Grassy Run was determined by records obtained at RG-3. Data for missing records were computed on the basis of weather records from nearby stations and the U.S. Weather Bureau at Elkins Airport.

Precipitation and runoff data for the Grassy Run-Roaring Creek watershed are presented in Table 8. Data are also given for Sand Run, a nearby unmined watershed, to allow comparison of runoff in mined and unmined areas.

Sand Run and Roaring Creek have similar runoff coefficients and runoff fluctuates directly with the yearly precipitation. Because the Roaring Creek watershed is large (72 square kilometers), and surface disturbance by mining is relatively small (4.5 percent of the watershed), the effect of mining on the precipitation/runoff relationship was insignificant. The watershed acts much like a watershed without mining. In contrast, values for Grassy Run exhibit an unusually high runoff coefficient. Because the Grassy Run watershed is small (10 square kilometers) the water diverted from Roaring Creek through the underground mine to Grassy Run affects the runoff coefficient significantly.

Increase in runoff in 1970 and 1971 on Grassy Run is attributed to deep mining near Norton and to high-intensity, short-duration storms. Although the mine at Norton was closed in August 1971, considerable water was released from the mine during retreating operations and subsequent removal of coal

TABLE 8. ANNUAL PRECIPITATION, RUNOFF, AND RUNOFF COEFFICIENTS FOR ROARING CREEK (R-1), GRASSY RUN (G-1), AND SAND RUN

Calendar year	Station	Precipitation, inches[a]	Runoff, inches[a]	Runoff coefficient
1965	R-1	39.01	22.01	56
	G-1	38.85	31.41	81
	Sand Run	34.76	19.36	56
1966	R-1	46.62	20.78	45
	G-1	43.05	27.99	65
	Sand Run	39.50	19.19	49
1967	R-1	57.09	31.28	55
	G-1	54.41	47.99	88
	Sand Run	53.50	29.69	55
1968	R-1	43.82	23.78	53
	G-1	42.73	33.45	78
	Sand Run	39.38	20.42	52
1969	R-1	51.06	24.76	49
	G-1	49.40	31.05	63
	Sand Run	49.27	25.02	51
1970	R-1	47.60	22.04	49
	G-1	44.71	39.83	89
	Sand Run	47.91		48
1971	R-1	43.79	27.65	63
	G-1	45.50	44.55	98
	Sand Run	41.66	22.83	54

[a] To convert from inches to centimeters multiply by 2.54.

pillars just before its closing. During 1971, periods of high rainfall during short-duration storms caused greater than normal runoff. For example, more than 20 centimeters of rain fell on the watershed within a 4-day period from September 12 to 15, 1971. This rain comprised 83 percent of the total precipitation for the month and about 20 percent of the total precipitation for the year. During this period the runoff coefficient was very high.

Detailed data on the subwatersheds and individual discharges are presented in the Appendices.

Chemical and Physical Characteristics of Surface Waters--

The water quality sampling program was established for two purposes:

(1) To aid in location of sources of mine pollution, and

(2) To indicate the effectiveness of at-source acid mine drainage control methods.

The first phase of this project was to locate all sources of mine drainage in the study-area watershed. A survey was made to locate all points of discharge into the principle streams, Roaring Creek and Grassy Run. Each discharge was then sampled and a chemical analysis performed. The analyses included pH, acidity (hot), alkalinity, iron, sulfates, aluminum, specific conductance, hardness, calcium, and magnesium. These water quality data indicated the severity of pollution at each discharge. With the aid of these data and mine maps, the reclamation plan for the watershed was formulated.

Materials and methods for analysis of chemical and physical characteristics--Since the purpose of the program was to demonstrate methods of controlling acid mine pollution at its source, it was imperative that the quality of the water be well documented before and after installation of corrective measures. Hence, water samples were collected not only from the mine discharges but also from the major streams and tributaries. Sampling sites along Roaring Creek and Grassy Run were selected to determine the influence of the major mine discharges upon sections of the stream. In this manner remedial work of a specific type could be evaluated by its effect on a section of stream or an individual discharge point. Since Roaring Creek and Grassy Run both are tributaries to the Tygart Valley River and are major sources of mine-derived pollutants of the river, sampling stations were established on the Tygart Valley River above and below the project area to show the influence of these tributaries (See Table 7 for summary of sampling stations).

In an effort to achieve a complete and meaningful picture of water quality, an intensive sampling program was established. The important mine discharge and stream sites were sampled on a weekly schedule, the less important sites on a monthly schedule, and a few sites on a work-load schedule. After the first year following completion of reclamation, sampling frequency was reduced to bi-weekly and for the last year, to monthly. The major emphasis was placed on the two gaging stations at the mouth of Roaring Creek and Grassy Run. As indicated earlier, permanent USGS gaging stations were located at these sites to provide continuous water flow records. During the early phases of the project, continuous water quality monitors were operated at these two gaging stations. These were later discontinued because acid and sediment caused pump malfunctions, and iron fouled the sensors. Weekly grab samples were used thereafter.

A flow measurement was made each time a water sample was collected. Special samples were also collected for detailed analysis of heavy metals.

Detailed data for each subwatershed are presented in the Appendices. Following is a summary of the water quality studies.

Physical and chemical characteristics of surface waters in Roaring Creek watershed--Monthly concentration and load data for Roaring Creek (Table 9) show clearly that the stream is grossly polluted with acid mine drainage.

The concentrations follow a seasonal pattern, the highest concentrations occuring during the low-flow period of late summer and early fall, and the lowest concentrations occuring during high-flow periods in the spring. This pattern indicates a dilution effect. However, since the load does not remain constant, but follows a seasonal trend, other factors are involved. During high-flow periods the concentrations remain higher than they should if dilution is the controlling factor. These high concentrations result from mine drainage pollutants being flushed from the mining system. Morth et al. (8) have reported on this phenomenon.

Table 10 summarizes the water quality of Roaring Creek prior to construction.

An analysis was made to identify the tributaries making the major contributions to Roaring Creek. As noted in Figure 11, White's Run, Kittle Run, and Flatbush Fork contributed over half of the pollution load. A significant amount of the load was being discharged to Roaring Creek as direct runoff from mine wastes. The major underground mine discharges to Roaring Creek are listed in Table 11. As noted, 1383 metric tons of sulfate were discharged from this source. The actual contribution of underground mines was probably somewhat higher because of under-

TABLE 9. MONTHLY AVERAGES OF WATER QUALITY DATA AND LOADS FOR ROARING CREEK (R-1) FROM MARCH 1964 - DECEMBER 1965

Year Month	Flow, cfs[a]			Acidity as $CaCO_3$		Total iron		Sulfate		Hardness as $CaCO_3$		Specific Conductance, µmhos/cm
	Max.	Min.	Ave.	mg/l	lbs/day[b]	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	
1964												
March	64.00	48.00	53.50	60	17,302	6.8	1,961	93	26,818	47	13,553	280
April	183.00	42.00	99.00	42	22,411	6.6	3,522	70	37,352	37	19,743	217
May	41.00	20.00	32.60	60	10,542	2.2	387	95	16,692	58	10,191	349
June	44.00	7.80	20.50	45	4,968	2.3	254	93	10,267	53	5,851	291
July	8.40	0.90	5.50	86	2,546	2.8	83	177	5,239	85	2,516	547
Aug.	12.00	0.80	3.70	139	2,766	3.5	70	206	4,099	149	2,965	709
Sept.	40.00	0.30	5.10	164	4,494	2.6	71	241	6,603	195	5,343	747
Oct.	6.60	1.60	3.00	142	2,286	7.1	114	237	3,816	156	2,512	673
Nov.	35.00	2.40	10.20	95	5,215	4.4	242	154	8,455	111	6,094	449
Dec.	103.00	17.00	52.00	48	13,450	1.9	532	78	21,856	54	15,131	240
1965												
Jan.	374.00	37.00	116.00	66	41,263	7.0	4,376	108	67,522	50	31,260	362
Feb.	289.00	26.00	101.00	57	31,025	6.2	3,374	108	58,784	53	28,843	363
March	317.00	58.00	135.00	38	27,649	2.7	1,965	72	52,387	40	29,104	266
April	185.00	90.00	129.00	46	31,984	4.6	3,198	76	52,843	40	27,812	293
May	37.00	10.00	26.00	65	9,107	3.2	448	111	15,551	58	8,126	396
June	8.00	1.14	3.30	149	2,637	5.1	90	252	4,460	124	2,195	756
July	9.30	0.78	3.74	163	3,276	3.9	78	280	5,628	137	2,754	808
Aug.	1.20	0.15	0.73	261	1,018	7.0	27	493	1,923	279	1,088	1,168
Sept.	1.40	0.37	0.77	242	992	8.7	36	352	1,443	234	959	1,148
Oct.	3.50	0.79	1.64	238	2,094	12.4	109	345	3,036	187	1,646	956
Nov.	5.50	1.26	3.40	231	4,227	12.7	232	298	5,453	148	2,708	903
Dec.	10.00	4.10	6.00	137	4,425	6.3	203	193	6,234	104	3,359	678
Yearly				2,920 Tons[c]		204 Tons		5,002 Tons				

(continued)

TABLE 9 (continued).

Year Month	Flow, cfs[a]			Acidity as $CaCO_3$,		Total iron		Sulfate		Hardness as $CaCO_3$		Specific Conductance,
	Max.	Min.	Ave.	mg/l	lbs/day[b]	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	μmhos/cm
1966												
Jan.	40.00	9.00	25.00	81	10,911	4.8	647	115	15,491	46	6,196	421
Feb.	142.00	28.00	61.00	85	27,939	8.6	2,827	130	42,731	54	17,750	456
March	259.00	26.00	81.00	76	33,174	6.5	2,837	101	44,087	46	20,079	417
April	379.00	53.00	150.00	52	42,042	5.1	4,123	89	71,957	41	33,149	350
May	213.00	24.00	77.00	78	32,370	6.4	2,656	120	49,800	57	23,655	451
June	38.00	1.10	16.46	98	8,692	3.6	319	144	12,773	79	7,007	558
July	12.00	0.22	3.26	270	4,725	11.7	205	358	6,265	199	3,483	1,008
Aug.	26.00	2.70	11.90	187	11,994	7.8	500	264	16,933	120	7,700	829
Sept.	30.00	3.00	14.50	157	12,270	7.9	617	250	19,538	128	10,003	771
Oct.	79.00	8.60	30.40	78	12,780	4.0	655	114	18,679	66	10,814	393
Nov.	26.00	11.00	18.60	58	5,812	3.2	321	95	9,519	---	------	341
Dec.	275.00	45.00	112.25	59	35,695	6.4	3,872	88	53,240	---	------	
Yearly				3,928 Tons		280 Tons		5,842 Tons				

[a] To convert ft^3/sec. to cm^3/sec. multiply by 7.87.

[b] To convert lbs/day to Kg/day multiply of 0.453.

[c] To convert short ton to metric ton multiply by 0.907.

TABLE 10. SUMMARY OF WATER QUALITY DATA FOR ROARING CREEK FROM MARCH 1964 - JUNE 1966

	Maximum, mg/l	Minimum, mg/l	Mean, mg/l
pH	4.1	2.7	3.3[a]
Acidity (as $CaCO_3$)	318	19	104
Iron (total)	19	0.8	5.4
Iron (ferrous)	3	0.5	1.3
Hardness (total as $CaCO_3$)	381	25	97
Calcium (as $CaCO_3$)	151	19	71
Magnesium (as $CaCO_3$)	70	6	16
Aluminum	29	0	11
Sulfate	520	29	166
Specific conductance, μmhos/cm	1310	110	528
Manganese	1.5	0.8	1.1
Zinc			0.24[b]
Cadmium			0.01[b]
Copper			0.03[b]
Lead			0.1[b]
Chromium			0.2[b]

[a] Median.

[b] One sample.

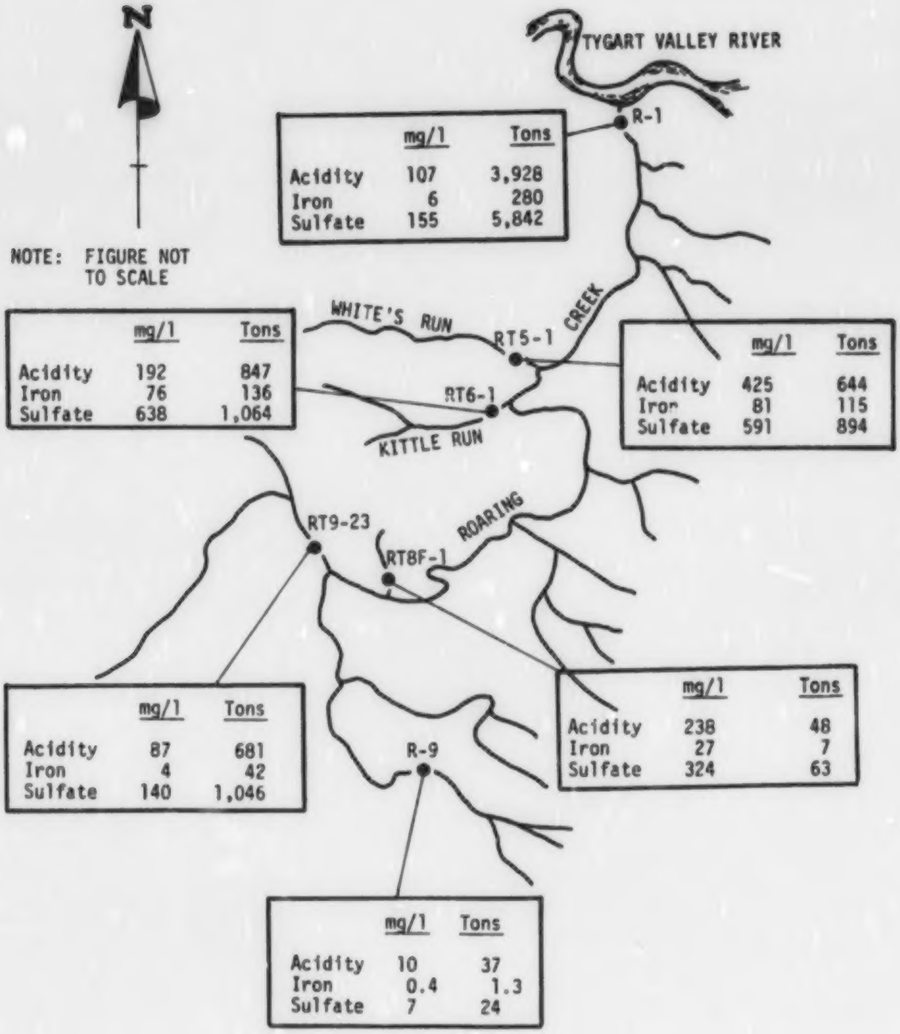

N
NOTE: FIGURE NOT TO SCALE
TYGART VALLEY RIVER
R-1
mg/l Tons
Acidity 107 3,928
Iron 6 280
Sulfate 155 5,842
WHITE'S RUN
RT5-1
CREEK
mg/l Tons
Acidity 425 644
Iron 81 115
Sulfate 591 894
RT6-1
KITTLE RUN
mg/l Tons
Acidity 192 847
Iron 76 136
Sulfate 638 1,064
RT9-23
ROARING
RT8F-1
mg/l Tons
Acidity 87 681
Iron 4 42
Sulfate 140 1,046
mg/l Tons
Acidity 238 48
Iron 27 7
Sulfate 324 63
R-9
mg/l Tons
Acidity 10 37
Iron 0.4 1.3
Sulfate 7 24

Figure 11. Acid mine drainage contributions to Roaring Creek by major tributaries - 1966.[a]

[a] To convert short tons to metric tons multiply by 0.907.

TABLE 11. MAJOR UNDERGROUND MINE DISCHARGES TO ROARING CREEK - 1966

	Acidity, tons	Iron, tons	Sulfate, tons
White's Run			
RT5-2	158	32	212
Kittle Run			
RT6-3	25	1	47
RT6-5	254	22	410
RT6-20	169	35	195
RT6-23	270	61	304
RT6-9	65	15	93
RT6-25	38	9	36
RT6-12	65	15	68
RT6-6A	25	3	22
Mabie Watershed			
RT8F-1	32	5	36
Middle Roaring Creek			
RT8F-5	14	1	32
RT8B-3	2	<1	18
Flatbush Fork			
RT9-11	18	2	26
RT9-5	19	3	25
RT9-20	3	1	5
TOTAL	1157	206	1529

[a] To convert short tons to metric tons, multiply by 0.907.

ground mine seepage that could not be measured directly. If it is assumed that the above figure is correct for underground mines, then 26 percent of the sulfate load in 1966 was from underground mines and the remainder from other sources such as spoil banks and refuse dumps. Sulfate was selected for the comparison because losses to neutralization and precipitation would be minor as compared to acidity and iron.

Sediment discharge, as reported by the USGS, is presented for 1965 and 1966 in Table 12. Flint reported that the sediment yield was low, 0.04 kg/m^3 runoff, and attributed this level to the fact that the surface mines had been inactive for several years.

Physical and chemical characteristics of surface waters in Grassy Run watershed--The monthly concentrations and load data for Grassy Run are presented in Table 13. The concentrations and loads follow the same seasonal trend shown for Roaring Creek. While discharges from Grassy Run were slightly less than from Roaring Creek, area concentrations and loads were much greater than for Roaring Creek because Grassy Run is a smaller watershed. In 1966 Roaring Creek discharged 3563 and 5299 metric tons of acidity and sulfate respectively, while Grassy Run discharged 3529 and 4452 metric tons respectively. During low-flow periods discharges from underground mines were the major portion of the Grassy Run flow. During the wet spring period, large quantities of pollutants were flushed from the large underground mine complex. The locations of major sources of acid mine drainage to Grassy Run are shown in Figure 12.

The major mine discharge, GT 6-1, contributed 55 and 51 percent of the acidity and sulfate loads, respectively, in 1966.

The water quality of Grassy Run is summarized in Table 14 and in the Appendices.

Sediment discharges as measured by the USGS are reported in Table 15. Although the sediment concentrations were usually higher than those in Roaring Creek, the level of 0.07 kg/m^3 runoff is low for Appalachian streams. The surface mines, (3.6 percent of the watershed), were several years old, relatively stable, and did not contribute major amounts of sediment.

Water quality summary for Roaring Creek and Grassy Run watersheds--For the *base* year of 1966 the combination of Grassy Run and Roaring Creek contributed acid mine drainage to the Tygart Valley River in the following amounts: acidity - 7092 metric tons, iron - 709 metric tons, and sulfate - 97,511 metric tons. Over half of this pollution load could be directly attributed to the underground mines.

TABLE 12. SEDIMENT DISCHARGE BY MONTHS FOR ROARING CREEK FROM 1965-1967

	Sediment concentration, mg/l	Sediment discharge, tons
1965		
February	16	48
March	48	549
April	42	574
May	8	16
June	4	1
July	7	2
August	11	0.4
September	1	0.1
October	11	2
November	4	1
December	3	1
1966		
January	18	46
February	86	722
March	23	125
April	40	340
May	39	228
June	7	7
July	5	1
August	17	13

(continued)

TABLE 12 (continued).

	Sediment concentration, mg/l	Sediment discharge, tons
September	13	13
October	119	267
November	36	81
December	26	149
1967		
January	16	47
February	24	108
March	172	3,330
April	16	85
May	116	1,420
June	83	138
July	68	161
August	240	475
September	751	942

[a] To convert short tons to metric tons, multiply by 0.907.

TABLE 13. MONTHLY AVERAGES OF WATER QUALITY DATA AND LOADS FOR GRASSY RUN FROM MARCH 1964 - DECEMBER 1965

Year Month	Flow, cfs[a]			Acidity as $CaCO_3$ [b]		Total Iron		Sulfate		Hardness as $CaCO_3$		Specific conductance, µmhos/cm
	Max.	Min.	Avg.	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	
1964												
March				688		104		963		374		1,600
April	29.00	8.50	16.40	468	41,367	84	7,425	672	59,398	299	26,429	1,412
May	8.00	3.80	5.43	675	19,751	107	3,131	983	28,763	464	13,577	1,988
June	4.40	2.30	3.26	605	10,630	88	1,546	973	17,096	480	8,434	1,841
July	2.90	1.70	2.15	696	8,060	113	1,309	1,054	12,205	471	5,454	2,070
August	2.00	1.20	1.60	722	6,224	117	1,009	1,294	11,154	597	5,146	2,073
Sept.	5.00	0.80	1.51	810	6,585	130	1,059	1,380	11,219	627	5,098	2,134
October	1.70	0.90	1.24	809	5,404	127	848	1,299	8,677	567	3,788	2,039
Nov.	2.60	0.90	1.38	781	5,803	117	869	1,192	8,857	566	4,205	1,960
Dec.	12.00	4.10	6.84	480	17,693	69	2,543	748	27,571	421	15,518	1,534
1965												
January	28.00	5.50	13.76	623	45,903	146	10,757	964	71,028	367	27,041	1,562
Feb.	23.00	8.80	12.37	621	41,402	129	8,600	1,069	71,270	417	27,801	1,660
March	23.00	11.00	15.60	409	34,389	80	6,726	706	59,360	280	23,542	1,233
April	23.00	14.00	17.00	489	44,807	93	8,521	750	68,723	289	25,481	1,302
May	9.20	3.60	6.45	576	20,022	110	3,824	963	33,474	379	13,174	1,580
June	4.40	1.85	2.62	644	9,093	99	1,398	1,056	14,911	457	6,453	1,623
July	1.85	1.00	1.60	627	5,405	94	810	1,108	9,551	476	4,103	1,622
August	1.20	1.00	1.05	794	4,486	113	638	1,215	6,865	519	2,932	1,765
Sept.	1.30	0.76	0.92	714	3,534	105	520	806	3,990	533	2,638	1,836
October	1.20	0.76	0.93	755	3,783	110	551	988	4,950	457	2,290	1,600
Nov.	1.30	0.76	1.07	658	3,790	106	611	928	5,345	449	2,586	1,568
Dec.	1.30	0.76	0.96	624	3,226	98	507	908	4,694	425	2,197	1,428
Yearly				3,715 tons[c]		715 tons		6,314 tons				

(continued)

TABLE 13 (continued).

Year Month	Flow, cfs[a]			Acidity as $CaCO_3$		Total Iron		Sulfate		Hardness as $CaCO_3$		Specific conductance, µmhos/cm
	Max.	Min.	Avg.	mg/l	lbs/day[b]	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	
1966												
January	3.60	1.50	2.48	596	7,963	98	1,309	813	10,862	363	4,850	1,462
Feb.	20.00	3.60	8.90	631	30,269	125	5,996	813	38,999	351	16,837	1,395
March	25.00	4.50	9.80	758	40,038	152	8,029	872	46,059	253	18,645	1,604
April	36.00	8.00	16.00	505	43,551	98	8,452	620	53,469	254	21,905	1,226
May	26.00	4.50	11.25	723	43,836	142	8,609	885	53,658	382	23,161	1,648
June	3.60	2.20	2.76	826	12,283	146	2,171	1,004	14,929	474	7,048	1,836
July	1.80	1.90	1.55	870	7,265	138	1,152	1,073	8,960	511	4,267	1,995
Aug.	2.90	1.20	2.00	692	7,460	104	1,121	936	10,090	449	4,840	1,964
Sept.	6.50	1.70	3.12	612	10,288	93	1,563	888	14,927	390	6,556	1,818
Oct.	4.50	1.50	2.40	670	8,663	124	1,603	878	11,353	390	5,043	1,765
Nov.	2.30	1.40	1.70	794	7,273	149	1,365	996	9,123	--	--	1,968
Dec.	21.00	5.50	10.57	213	12,135	93	5,298	698	39,765	--	--	1,351
Yearly				3,891 tons		691 tons		4,909 tons				

[a] To convert ft^3/sec to cm^3/sec, multiply by 7.87.
[b] To convert from lbs/day to kg/day, multiply by 0.454.
[c] To convert from short tons to metric tons, multiply by 0.907.

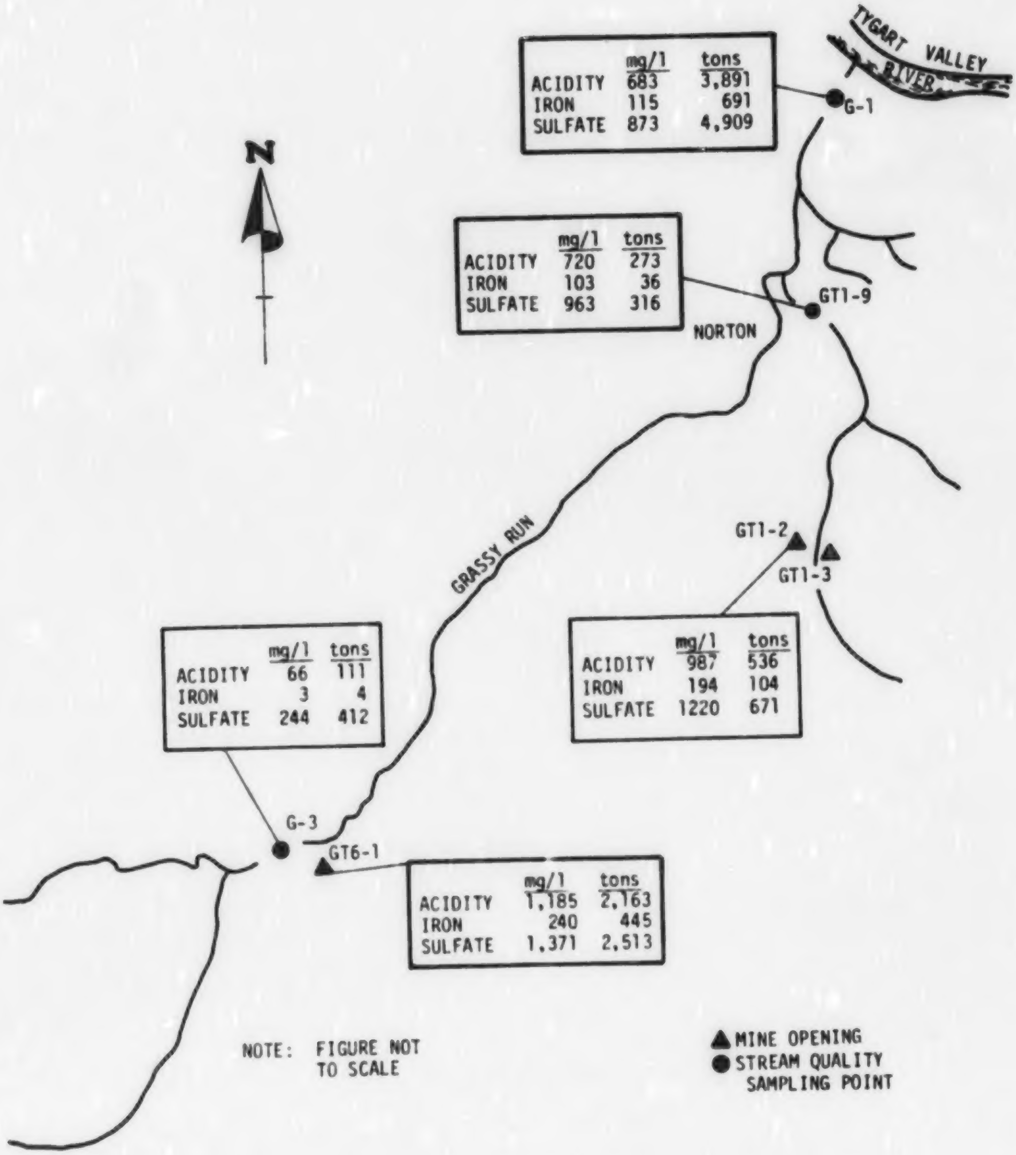

TYGART VALLEY
RIVER
N
G-1
mg/l tons
ACIDITY 683 3,891
IRON 115 691
SULFATE 873 4,909
GT1-9
mg/l tons
ACIDITY 720 273
IRON 103 36
SULFATE 963 316
NORTON
GRASSY RUN
GT1-2
GT1-3
mg/l tons
ACIDITY 987 536
IRON 194 104
SULFATE 1220 671
G-3
mg/l tons
ACIDITY 66 111
IRON 3 4
SULFATE 244 412
GT6-1
mg/l tons
ACIDITY 1,185 2,163
IRON 240 445
SULFATE 1,371 2,513
NOTE: FIGURE NOT TO SCALE
▲ MINE OPENING
● STREAM QUALITY SAMPLING POINT

Figure 12. Acid mine drainage contributions to Grassy Run - 1966.[a]

[a] To convert short tons to metric tons multiply by 0.907.

TABLE 14. SUMMARY OF WATER QUALITY DATA FOR GRASSY RUN FROM MARCH 1964 - JUNE 1966

	Maximum, mg/l	Minimum, mg/l	Mean, mg/l
pH	3.4	2.4	2.8[a]
Acidity (as $CaCO_3$)	980	208	656
Iron (total)	260	31	110
Iron (ferrous)	7.0	1.8	4.4
Hardness (total as $CaCO_3$)	744	146	420
Calcium (as $CaCO_3$)	380	223	308
Aluminum	72	10	38
Sulfate	1650	310	950
Specific conductance, (µmhos/cm)	2320	720	1670
Manganese	2.9	1.2	1.7
Zinc	1.0	0.3	0.5
Cadmium	<0.01	<0.01	<0.01
Copper	0.2	0.1	0.15
Lead	<0.1	<0.1	<0.1
Chromium	<0.02	<0.02	<0.02
Boron	<0.02	<0.02	<0.02
Molybdenum	0.3	0.1	0.1
Silver	<0.01	<0.01	<0.01
Nickel	0.3	0.2	0.26
Cobalt	0.1	0.1	0.1
Vanadium	<0.1	<0.1	<0.1
Barium	<0.1	<0.1	<0.1
Strontium	0.08	0.06	0.07
Total carbon	<1	<1	<1
COD	153	<40	-

[a] Median value.

TABLE 15. SEDIMENT DISCHARGE BY MONTHS FOR GRASSY RUN FROM 1965-1967

	Sediment concentration, mg/l	Sediment discharge, tons[a]
1965		
February	51	25
March	77	106
April	53	101
May	16	8
June	19	4
July	33	5
August	19	2
September	33	3
October	32	3
November	20	2
December	18	2
1966		
January	66	18
February	147	140
March	54	40
April	153	173
May	32	29
June	11	2
July	12	2
August	39	6
September	22	5
October	32	7.0
November	41	9
December	27	17.0
1967		
January	20	9
February	27	16.0
March	188	650
April	22	19
May	42	73
June	11	6
July	52	14
August	34	7
September	83	16

[a] To convert short tons to metric tons, mulitply by 0.907.

The monitoring stations on the Tygart Valley River were inadequate for measuring the effects of Grassy Run and Roaring Creek on the river because the discharge from the two streams did not readily mix with the river.

Biological Characteristics of Surface Waters--

As indicated earlier, the chemical compounds common to drainage water from coal mines include sulfuric acid and the acid salts of iron, aluminum, zinc, lead, and copper. Complex mixtures of these chemicals may be toxic to animals in the concentrations commonly encountered (9).

Aquatic organisms respond in many ways to various types of pollution. Waters that are not polluted are generally inhabited by great varieties of organisms, both tolerant of and sensitive to pollution. Conversely, polluted waters generally support only a few varieties of organisms that are tolerant of the pollution (these tolerant organisms may also inhabit nonpolluted waters, along with pollution sensitive organisms). For these reasons, comparisons of organisms in polluted waters with those in similar, nonpolluted waters are useful in delineating the effects and extent of pollution.

In the Roaring Creek and Grassy Run watersheds, one would suspect that the large quantities of acid mine drainage pollutants have produced highly restrictive environments capable of supporting only a specialized assemblage of tolerant plants and animals. With this in mind, biological surveys were conducted at the project site in order to:

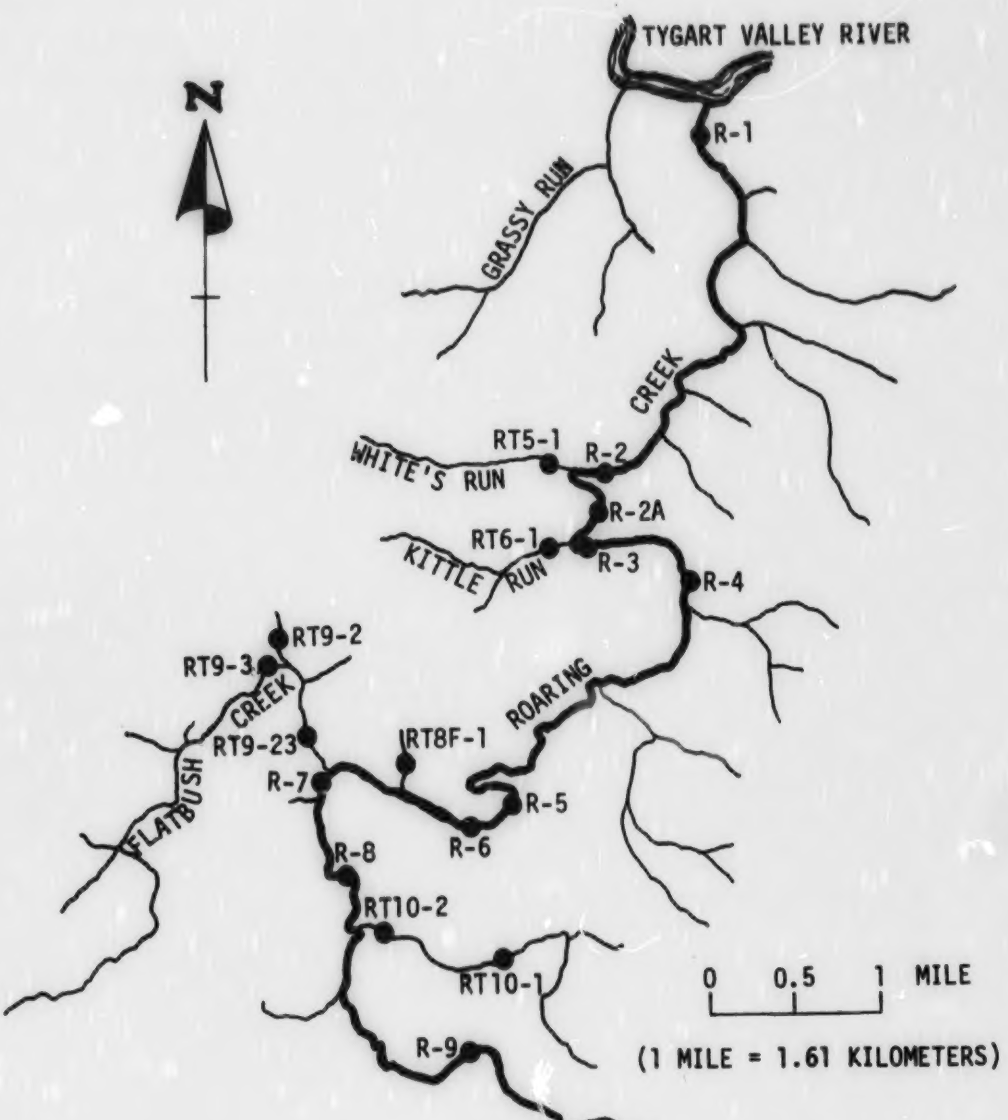
(1) describe the biological communities present in the streams of the watershed prior to reclamation,

(2) assess the effects of acid mine drainage on the biota of the streams, and

(3) generate baseline data to be compared to postreclamation data.

The investigations were carried out in the mainstream of Roaring Creek and in several selected tributaries. The biology of Grassy Run was not evaluated.

Materials and methods (benthos and periphyton)--The biological investigations were carried out simultaneously with the physical-chemical studies. Sampling was done at 15 stations along Roaring Creek and selected tributaries (Figure 13). The studies were conducted during winters, springs, summers, and falls from June 1965 to July 1967. Qualitative samples of bottom-dwelling invertebrates were collected by picking and scraping the bottoms of rocks and logs and by agitating debris in a sieve (U.S. Standard No. 30). No quantitative data are



TYGART VALLEY RIVER
N
GRASSY RUN
CREEK
R-1
RT5-1
R-2
WHITE'S RUN
R-2A
RT6-1
R-3
KITTLE RUN
R-4
RT9-2
RT9-3
CREEK
ROARING
RT9-23
RT8F-1
FLATBUSH
R-7
R-5
R-6
R-8
RT10-2
RT10-1
R-9
0
0.5
1
MILE
(1 MILE = 1.61 KILOMETERS)

Figure 13. Location of biological sampling stations.

available. Benthos samples were preserved in 10 percent formalin solution. Qualitative samples of periphyton were collected by scraping rocks, twigs, and other substrates. Qualitative samples were examined live, then were preserved in 5 percent formalin for detailed examination at high magnification. Diatoms were incinerated in nitric acid and potassium dichromate and permanently mounted on microscopic slides and examined at 1,175X.

Identification of most of the algae and benthic organisms was done at EPA water quality laboratories at Cincinnati, Ohio.

Material and methods (fish)--In 1965 the U.S. Fish and Wildlife Service completed an initial quantitative and qualitative inventory of the fish populations within the Roaring Creek watershed. Existing upstream and downstream limits, densities, and species compositions of the fish populations were determined and mapped.

Results (benthos)--Some benthic invertebrates in Roaring Creek and its tributaries resisted the toxic effects of the acid mine drainage and the deleterious effects of smothering blankets of deposits of iron salts better than did others (10). The polluted reaches of Roaring Creek (median pH values of less than 3.8) supported far less diversity of bethnic communities than did those reaches less heavily polluted by mine drainage. Preferences for certain physical habitats influenced the distribution of pollution-tolerant species; for example, *Chironomus plumosus* was most abundant in reaches with a soft stream bed, and *Ptilostomis sp.* inhabited slack-water reaches. Some investigators have concluded that the distribution of acid-tolerant *Tendipes* (Chironomus) *plumosus* in coal-mine drainage was dependent on the presence of submerged leaf litter (11).

Headwater and tributary reaches of Roaring Creek not severely polluted by acid-mine drainage (median pH values of 4.5 and greater) supported relatively complex communities of benthic animals; for example, stations R-9 (pH 5.7), R-8 (pH 4.5), RT10-1 (pH 5.1), and RT10-2 (pH 4.9) were each inhabited by 25 or more species (10). Conversely, stream reaches that received heavy loadings of acid supported fewer species of invertebrates; many of these species also inhabited nonpolluted reaches. All mainstream reaches of Roaring Creek downstream from Station R-7 (river km 14.1), the reaches most heavily polluted, were inhabited by fewer than 13 invertebrate species, and the most severely polluted reaches were inhabited by less than 9 kinds of benthic invertebrates (Figure 14). Tributary streams very near mine sources (e.g., station RT5-1) were often uninhabited, and never supported more than 3 kinds of invertebrates.

A number of bottom-dwelling animals, including the alder fly (*Sialis sp.*), the bloodworm midge (*Chironomus plumosus*) and

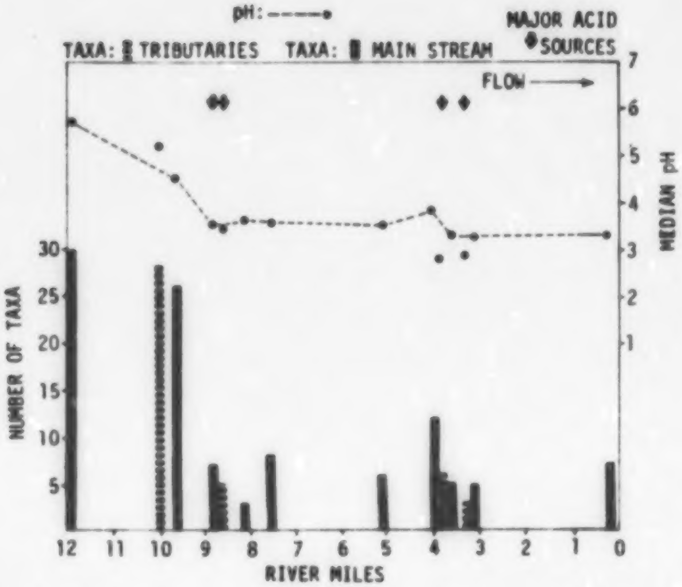


Figure 14. Distribution of benthic invertebrates, Roaring Creek, June 1964 to July 1967. (1 mile equals 1.61 kilometers).

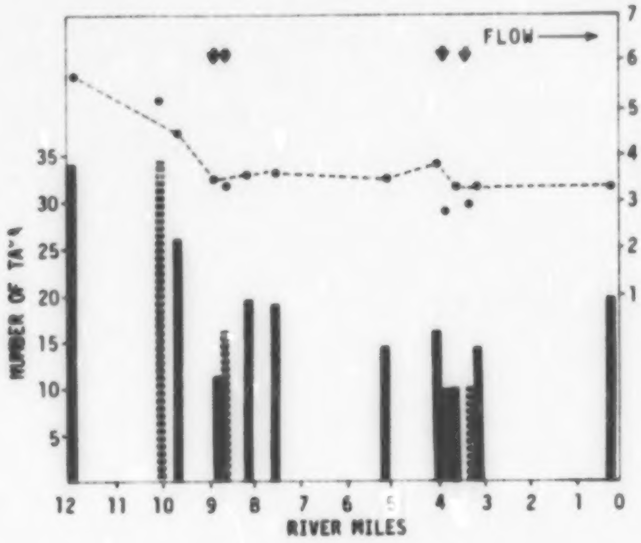


Figure 15. Distribution of periphyton, Roaring Creek, June 1964 to July 1967. (1 mile equals 1.61 kilometers).

other species of Chironomidae, and the dytiscid beetle, tolerated very strong concentrations of acid mine wastes. These forms were locally abundant in severely polluted reaches; up to 16,675 individuals per m^2 of *Chironomus plumosus* were collected (with an Ekman dredge) from a swampy area having a median pH of 2.8. During the summer months, the caddis fly, *Ptilostomis sp.*, was found in slackwater reaches of all stations, regardless of the pH of the stream.

Most sensitive to acid pollution among benthic invertebrates of common occurrence in headwater and nonpolluted reaches were black flies, crayfish, May flies, stone flies, and many species of caddis flies. All of these forms were repeatedly collected at stations with median pH values of 4.5 and higher but were never collected from reaches with median pH values below 4.5.

Results (periphyton)--Periphytic communities in Roaring Creek responded to the effects of acid mine pollution in a manner similar to that of the benthic invertebrates. Stream reaches with little or no acid pollution (pH 4.9 and higher) supported diverse periphytic communities consisting of 33 or more species (10). Conversely, severely polluted stream reaches (pH 3.8 and lower) were inhabited by fewer than 20 species. The smothering effect of heavy blankets of iron salts influenced the periphytic communities. For example, station R-7 (pH 3.5), in a stream bed heavily coated with iron salts supported only up to 13 periphyton species; stations R-6 (pH 3.6) and R-5 (pH 3.6), with clean stream beds, supported 19 and 18 species, respectively (Figure 15). Tributary streams near mine openings (e.g., RT5-1) supported no more than 10 species, and at times no more than 3 species were found in such places.

Among the 64 species of periphyton collected from Roaring Creek 10 species (*Ulothrix tenerrima*, *Microthamnion strictissimum*, *Microspora pachyderma*, *Closterium acerosum*, *Chlamydomonas sp.*, *Eunotia exigua*, *Pinnularia termitina*, *Frustulia rhomboides*, *Surirella ovata*, and *Euglena mutabilis*) were particularly tolerant of severe acid mine-pollution. Only *Ulothrix tenerrima*, *Pinnularia termitina*, *Eunota exigua*, and *Euglena mutabilis* were present in large numbers, always in the more acid reaches. Some tributary streams in which the major portions of flow originated from mines contained flowing masses of *Ulothrix sp.* with some *Eunotia sp.* and *Pinnularia sp*. The beds of other tributary streams were coated with green slimes of hundreds of thousands of individuals of *Euglena sp.* per cm^2 (estimated by exposing glass slides in the stream for 2 to 6 weeks, then counting the attached algae), mixed with large numbers of *Pinnularia sp.* and *Eunotia sp*. Although other tolerant species of algae were found inhabiting the acidic reaches of Roaring Creek, they were never abundant.

Results (fish)--Fish generally do not inhabit waters severely polluted by mine drainage (12 and 13). The surveys of Roaring Creek by the U.S. Fish and Wildlife Service revealed fish populations inhabiting only those reaches of the stream where the median pH was 4.9 or higher (R-9, pH 5.7; RT10-1, pH 5.1; RT10-2, pH 4.9; and two small nonpolluted tributaries). Fish found in the Roaring Creek basin were brook trout (*Salvelinus fontinalis*), mottled sculpin (*Cottus bairdi*), blacknose dace (*Rhinichthys atratulus*), and creek chub (*Semotilus atromaculatus*). The greatest production of fish was 24 kilograms per hectare, recorded in Seven Pines Run. The largest fish encountered was a brook trout measuring 20 centimeters in length and weighing 113 grams.

Thirteen species of fish were found in the Tygart Valley River 2.4 kilometers above the junction with Roaring Creek. The river at this point is a popular sport fishing area and samples disclosed a fish population of 1610 kilograms per hectare. The sample obtained 2.4 kilometers below the convergence of Roaring Creek and Grassy Run disclosed no fish life.

Groundwater

Basic Groundwater Patterns--

There are basic groundwater patterns which are characteristic to all watersheds. These generalized patterns are discussed in the following paragraphs according to several situations which can exist in a watershed. These situations include:

- Pre-mining hydrology.
- Post-mining hydrology.
- Water movement on updip side of a coal seam.
- Water movement on downdip side of a coal seam.

In a watershed without mining, precipitation that reaches the land surface either returns to the atmosphere by evapotranspiration, enters surface waters by runoff or enters the groundwater. Figure 16 depicts a typical premining situation. Prior to mining, relatively small amounts of water percolate downward because of the relative impermeability of the underlying rock.

The effect of underground mining and the subsequent fracture of overlying formations is to reverse the relative amounts of runoff and downward percolation. The gross permeability of soil and rock formations changes radically. In areas where fractures approach the land surface, the situation shown in Figure 17 occurs. Water moves downward easily through the fracture system at the expense of normal surface runoff. This

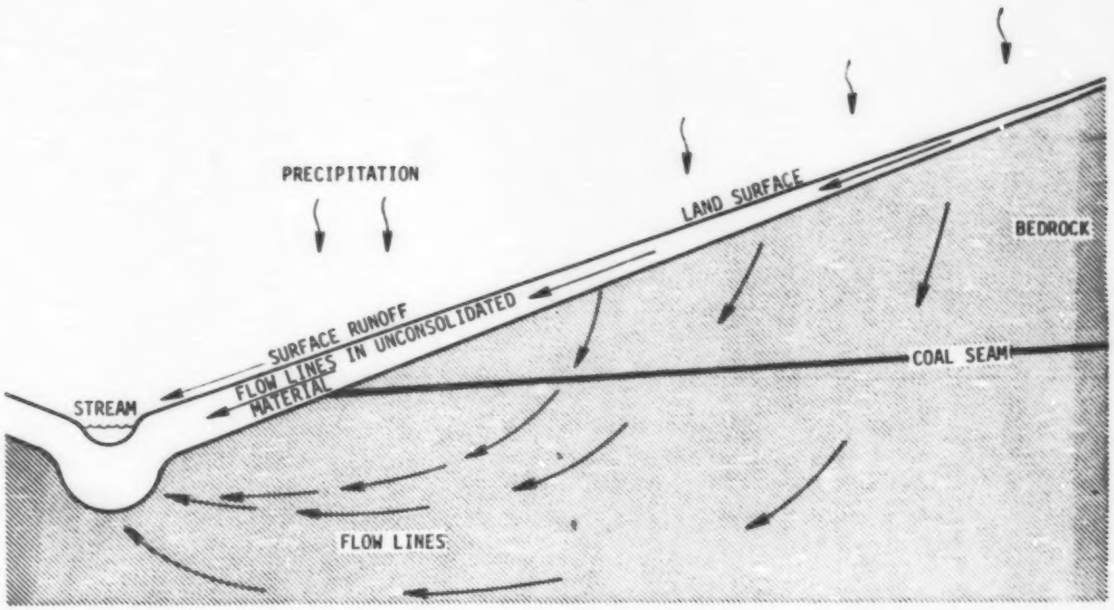

PRECIPITATION
LAND SURFACE
BEDROCK
SURFACE RUNOFF
FLOW LINES IN UNCONSOLIDATED MATERIAL
STREAM
COAL SEAM
FLOW LINES

Figure 16. Pre-mining hydrology.

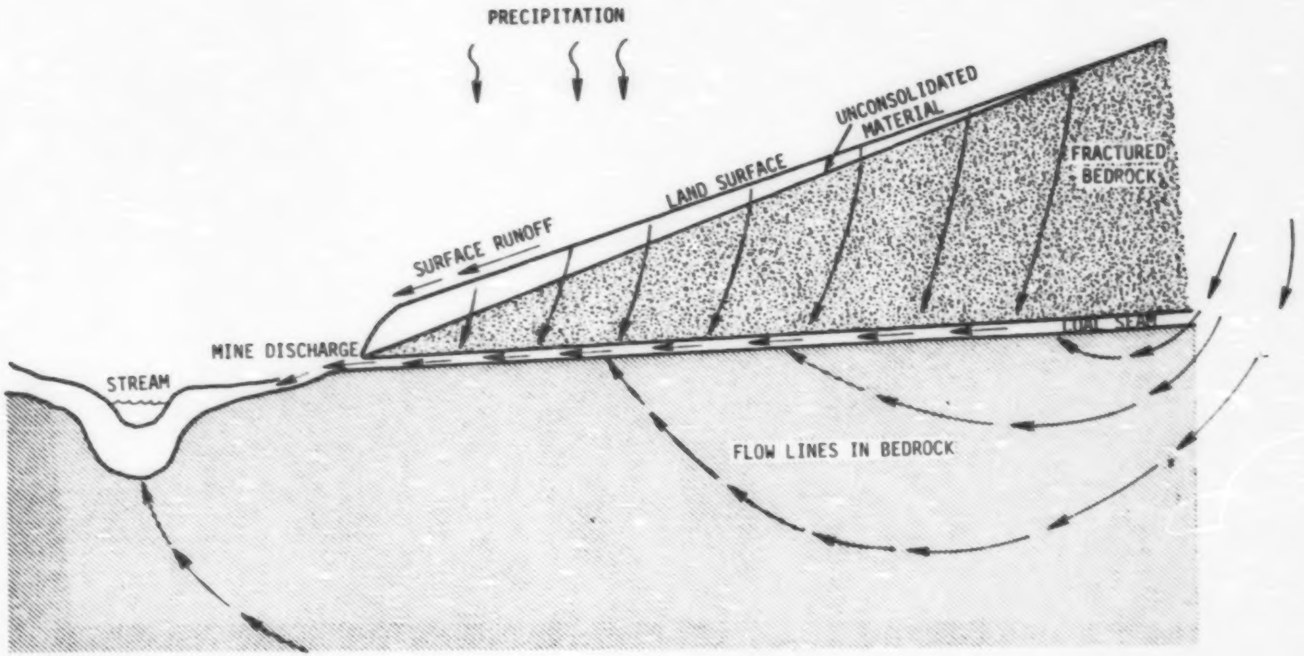

PRECIPITATION
UNCONSOLIDATED MATERIAL
LAND SURFACE
FRACTURED BEDROCK
SURFACE RUNOFF
COAL SEAM
MINE DISCHARGE
STREAM
FLOW LINES IN BEDROCK

Figure 17. Post-mining hydrology.

is a typical situation in the mined portions of the project area.

At sites where both deep and strip mining have occurred, the hydrology is slightly more complicated, as shown in Figure 18. Water enters the underground mine not only through the fractured overburden, but also as surface drainage down the face of the highwall and into the underground workings. This situation was noted in large portions of Roaring Creek. When the slope of the mine is reversed, as in Figure 19, water discharges from mine openings and fractures in the highwall and moves through and over the spoil piles enroute to the surface streams. This situation was found in the Grassy Run watershed.

The sketches and the situations described here were found throughout the project area. In some areas, especially those with thick overburden above a deep mine, the fractures probably do not approach the surface. In these areas the surface runoff is probably unaffected; however, as the water moves downward across the land surface, there is ample opportunity for interception by fractures and subsidence features, which are prevalent near the highwalls of strip mines. An actual example of this situation is a stream located near Coalton that completely disappears into the underground workings.

In and near a mined-out area, the mine floor can be considered as the base level that governs the movement of water entering the hydrological system as precipitation. A layer of impervious clay underlies the coal. Water enters the mine from above and moves downward through formations varying in permeability according to their degree of fracture. Additionally, artesian pressure within the formations that underlie the mine floor is probably great enough to cause some upward movement of water into the mines.

Troughs and ridges in topography also divert and direct movement of the mine water. At the Elkins site, troughs and ridges influence water flow in such a way that the initial movement of water is down the flanks and toward the axes of synclinal structures. The final movement is northward following the plunge of major synclines at a rate of 9.6 to 12.4 meters per km. The axes of the West Fork of the Belington syncline and of the main Belington syncline pass through the mine drains at GT-6-1 and the main portals, GT-1-2, respectively. Separating these two synclines is an anticlinal fold of low amplitude.

Drilling Program--

An integral part of the drilling program was to utilize the boreholes not only for study of the subsurface geology and extent of underground mines, but also as groundwater observation wells. In 1964, 28 boreholes were drilled. In addition, private and municipal wells, mostly in the unmined part of the watershed, were inventoried.

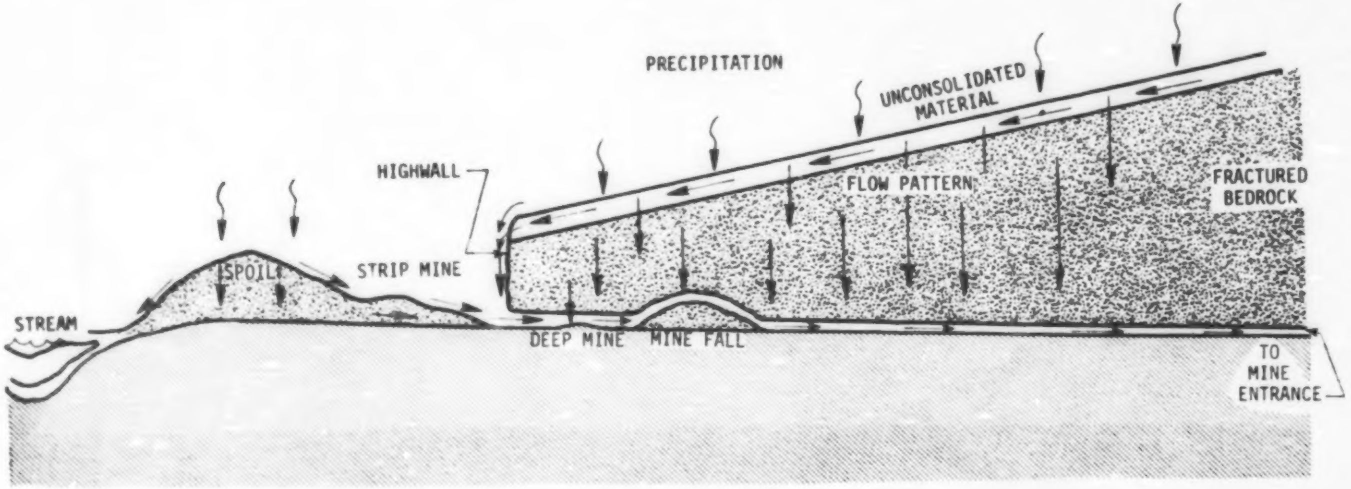

PRECIPITATION
UNCONSOLIDATED MATERIAL
HIGHWALL
FLOW PATTERN
FRACTURED BEDROCK
SPOIL
STRIP MINE
STREAM
DEEP MINE
MINE FALL
TO MINE ENTRANCE

Figure 18. Water movement affected by strip and underground mining (Updip side of coal seam).

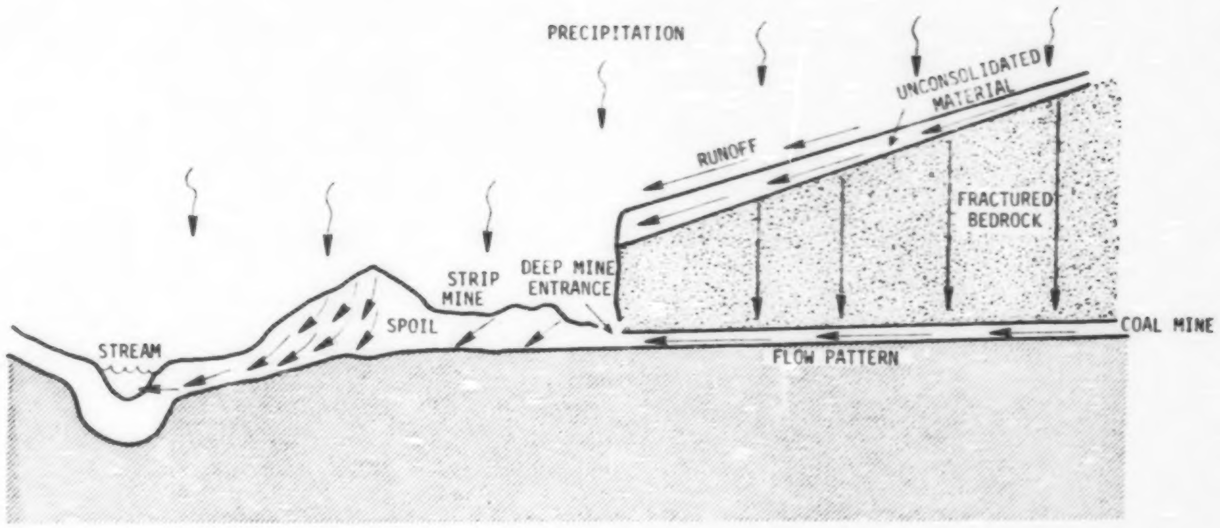

PRECIPITATION
UNCONSOLIDATED MATERIAL
RUNOFF
FRACTURED BEDROCK
STRIP MINE
DEEP MINE ENTRANCE
SPOIL
STREAM
COAL MINE
FLOW PATTERN

Figure 19. Water movement affected by strip and underground mining (downdip side of coal seam).

Core hole numbers used in the text and on the maps of this report are abbreviations of a three-part numbering system of the USGS in the West Virginia District. Holes drilled during 1964 are numbered from 15 through 37b, their locations are shown in Figure 7. The wells and springs inventoried in 1966 are numbered 38 through 174. Shortly after the initiation of the project, private wells and springs were no longer sampled.

Most of the 28 holes drilled for the project in 1964 were sited above or very near the deep mine so as to indicate the lateral extent of the mine. Some holes penetrated solid coal and others entered the void spaces and fracture systems of the mined-out areas. Some of the physical characteristics of these holes are listed in Table 16.

Eighteen of the holes were drilled with coring equipment for a total depth of 963 meters. The remaining ten were drilled by large-diameter cable-tool drill; total depth was 390 meters.

Extensive fracturing was noted in many parts of the project area. The cluster composed of core holes 21a, b, c, and d is a prime example. While drilling core hole 21d, operators noted considerable fracturing and core loss below a depth of 30.5 meters. The water level in nearby core hole 21a rose 10.4 meters because of the entry of drilling water from 21d. In view of the tightness of formation and the short time involved, it is assumed that movement of water was through part of a fracture system.

By 1967 only 658.8 meters of the original 1353 meters of core hole depth remained effective. Most of the loss was attributed to water loss in the wells due to fractures in the strata or to plugging by collapse of the borehole. Loss figures also include the immediate loss of core holes 15, 27, and 28 which were not completed and later losses that occurred when core holes 23, 30, 31, and 32 were plugged so that they would hold water.

Some losses are attributed to rock collapse above the deep mine and, to a lesser degree, to continued mining activity. The attrition due to collapse is prolonged and apparently involves a series of subsurface movements. Core hole 26b, for example, although protected by heavy-duty casing, lost 12.2 meters of depth in at least three increments of 4.6, 4.1 and 3.5 meters.

The losses related to continued mining often involved core holes that penetrated supporting pillars of coal. Subsequent pillar robbing removed the water-bearing strata from around the core holes and the local water table dropped to the level of the water on the mine floor. This was probably the case with core hole 36a, whose water level rather abruptly dropped from a range of 623.8 meters above mean sea level (msl) to 622.6 meters above

TABLE 16. PHYSICAL CHARACTERISTICS OF CORE HOLES DRILLED IN 1964

Core hole number[a]	Type of hole	Casing diameter, inches[b]	Depth when drilled, feet[c]	Depth when finished, feet[c]	Depth in 1967, feet[c]	Msl[e] altitude, bottom of present hole	Msl[e] altitude, base of mined coal
15	Core	2 1/2	177	0-dry	0-dry	--	--
16	Core	2 1/2	243	243	243	1876	2140
21a	Cable tool	6	175	175	170	2232	2256
21b	Cable tool	6	147	147	135[d]	2277	2256
21c	Cable tool	6	54	54	54	2357	2255
21d	Core	2 1/2	378	378	plugged[d]	--	--
22	Core	2 1/2	66	66	62	2112	2060
23	Core	2 1/2	135	81	79	2180	2127
24	Core	2 1/2	134	134	127	2043	2148
25	Core	2 1/2	294	294	290	1914	2054
26a	Core	2 1/2	198	198	194	2203	2240
26b	Cable tool	6	195	195	155[d]	2246	2240
26c	Cable tool	6	59	59	39	2339	2240
27	Core	2 1/2	114	0-dry	0[d]	--	--
28	Core	2 1/2	114	0-dry	0[d]	--	--
29	Core	2 1/2	157	157	157	2261	2254
30	Core	2 1/2	125	78	68	2295	2239
31	Core	2 1/2	105	78	68	2345	2313
32	Core	2 1/2	204	146	146	2213	2154
33a	Cable tool	6	172	172	159[d]	2156	2173
33b	Cable tool	6	136	136	136[d]	2170	2173
34	Core	2 1/2	257	257	243	2059	2205
35	Core	2 1/2	223	223	221	2275	2493
36a	Cable tool	6	156	156	154[d]	2029	2042
36b	Cable tool	6	117	117	113[d]	2074	2042
36c	Cable tool	6	69	69	58[d]	2128	2042
37a	Core	3	133	133	133[d]	2133	2123
37b	Core	3	162	162	162[d]	2104	2123

[a] See Figure 7.

[b] To convert inches to centimeters multiply by 2.54.

[c] To convert feet to meters multiply by 0.305.

[d] Dry or otherwise useless as observation wells.

[e] Msl - mean sea level.

msl. According to the mine map and log of the well, 622.6 meters represents the altitude at the base of the mined coal.

In similar instances, mining has resulted in drainage of water from enclosing rock near core holes, probably the cause of the drying up of core holes 33a, 37a, and 37b. The mining may not have been in the immediate area of the core holes but it was close enough to affect the hydrology of the groundwater.

The water-level measuring point for all project core holes is at, or very near, the top of the casing. In dug core holes, a reference mark was usually affixed to the inside, upper portion of the casing. The altitudes of these reference points were determined by instruments for all core holes drilled in 1964, and the same was done for measuring points of many core holes added to the network by inventory in 1966. Accuracy is to the nearest hundredth of a foot. Altitudes of measuring points and water levels of these core holes are given in Table 17.

Permeabilities were determined for 78 core samples taken at representative stratigraphic horizons. All showed exceptionally low coefficients of permeability, ranging from 0.0016 to 4.0 cm^3 per day per cm^2. In many areas such formations would be classed as aquicludes or barriers, relatively impermeable to the passage of water. It is likely that because of fracturing, the effective permeabilities of many of these strata exceed those indicated by the laboratory measurements of samples. Also, as viewed along the highwalls of the strip mines, there are marked lateral changes in rock texture, porosity, and cementation - changes that would create differences in permeability.

The relative impermeability of the core samples tested is the result of thorough cementation, with attendant lack of pore space and a low degree of interconnection between pores. During the drilling of wells and core holes in 1964, many water-bearing zones were encountered, but in each instance the water seemed to come from fractures or from the contact zones between formations.

If these permeabilities are representative of conditions throughout the basin, most water movement must take place through fracture systems that result from underground mining. In countless instances where pronounced and/or incipient fractures and subsidence features extend either to the land surface or to the zone of perched water, the water moves downward to become a part of the mine drainage system.

On the basis of information gathered during drilling and monitoring of core holes, it appears that in regard to the strata above and near the deep mine, only mass permeability should be considered. Conditions vary so greatly from one hole site to another that no comparisons of permeabilities could be made.

TABLE 17. FLUCTUATIONS OF WATER LEVELS IN CORE HOLES

Core hole number	Depth of core hole below land surface, feet[a]	Measuring point altitude above msl, feet	Water level, depth in feet below measuring point					
			1965 high, feet	1965 low, feet	1966 high, feet	1966 low, feet	1967 high, feet	9 months low, feet
16	243	2118.87	19.13	28.38	21.30	24.53	19.61	22.73
21a	170	2415.29	129.60	140.27	133.40	138.37	133.42	136.73
21c	54	2415.19	23.34	25.30	20.57	25.23	23.48	27.60
22	62	2179.11	41.09	44.99	28.49	41.16	23.41	29.89
23	79	2263.36	36.00	46.72	33.84	44.63	28.95	39.43
24	127	2271.93	11.13	27.15	13.38	22.84	10.51	20.63
25	290	2205.56	16.34	32.05	18.07	25.10	14.76	21.75
26a	194	2400.47	--	--	48.59	143.42	46.23	139.86
26c	39	2400.48	21.35	36.13	20.33	29.44	18.28	27.38
29	157	2418.11	25.60	45.33	18.98	36.72	17.16	33.02
30	68	2363.97	12.74	24.50	12.60	23.69	12.72	15.62
31	68	2424.55	12.99	43.76	11.0	29.27	10.24	19.11
32	146	2358.78	52.40	78.60	47.66	67.72	47.50	65.75
34	243	2302.19	35.84	48.34	36.67	45.21	31.54	39.35
35	221	2498.25	24.13	84.00	25.52	60.90	22.20	70.32
51	25	--	--	--	--	--	6.92	22.85
57	43	--	--	--	--	--	7.70	15.93
62	9	--	--	--	--	--	5.07	11.38
67	89	2396.73	--	--	--	--	44.13	69.29
74	145	2255.89	--	--	--	--	32.76	35.87
75	49	2260.90	--	--	--	--	14.15	22.86

(continued)

TABLE 17 (continued).

Core hole number	Depth of core hole below land surface, feet[a]	Measuring point altitude above msl, feet	Water level, depth in feet below measuring point					
			1965 high, feet	1965 low, feet	1966 high, feet	1966 low, feet	1967 high, feet	9 months low, feet
81	44	2243.98	--	--	--	--	16.07	18.90
92	11	2438.61	--	--	--	--	1.88	7.57
93	54	2454.11	--	--	--	--	4.03	5.31
95	22	2366.97	--	--	--	--	3.70	7.00
96	30	2420.96	--	--	--	--	12.46	22.07
98	19	2239.60	--	--	--	--	2.50	10.13
102	46	2331.68	--	--	--	--	16.70	20.43
107	66	2466.82	--	--	--	--	23.70	31.45
109	155	2173.81	--	--	--	--	11.71	17.33
110	191	2172.98	--	--	--	--	10.85	15.92
112	34	--	--	--	--	--	14.71	33.43
116	31	2573.72	--	--	--	--	7.67	9.78
119	14	--	--	--	--	--	3.17	7.60
122	68[a]	--	--	--	--	--	12.25	20.01
124	151	2229.51	--	--	--	--	67.35	71.38
126	105[b]	--	--	--	--	--	5.61	9.07
132	317[a]	--	--	--	--	--	Flowing	
136	104	--	--	--	--	--	0.45	3.79
143	124	2379.15	--	--	--	--	89.00	96.60
149	22	--	--	--	--	--	13.57	18.53
155	21	--	--	--	--	--	4.04	18.63
158	37	--	--	--	--	--	12.73	16.88
168	35	--	--	--	--	--	10.15	29.99

[a] To convert feet to meters, multiply by 0.305.
[b] R = reported.

The only large quantities of water encountered during drilling originated from fractures or from contacts between formations. Shales often supplied more water than did the coarse but well-cemented sandstones, apparently because of slight fracturing which permitted good lateral movement of water. Some movement of subsurface water in the zone of aeration above the deep mines also takes place through the interconnected pore spaces of the rock and soil, especially near the land surface; however, the rate of movement is very much slower than that of water traveling through the fracture system.

Underground Mine Water Movement--

Dye studies were conducted to determine the direction and speed of water movement through the mine. A fluorometer was used to read concentrations of fluorescent dye injected into the water. Rhodamine B and Pontacyl Pink dyes were used in these studies; the latter is subject to less deterioration under acidic conditions. Water samples were collected at proposed sample sites prior to release of the dye so that background interference could be determined.

After injection of the dyes into the mine water, samples were collected daily at sampling points discharging at the lower side of the coal seam. Contour mine maps and knowledge of the mine drainage patterns were the basis for determining the probable direction of flow and approximate distances. The approximate direction the dye traveled in each study is shown in Figure 20. The first study was conducted on October 19, 1966. At RT6-24 sample point, 7.6 liters of Rhodamine B dye were injected into the mine. In 10 days the dye was detected at RT5-2, a distance of 1280 meters. The flow rate was determined to be 128 meters per day. The dye concentrations peaked 24 days after dosing. Concentrations were in the range of 6 ppb (parts per billion). GT1-1, GT1-2, and GT6-1 were checked daily but showed no signs of dye.

A second dye study was conducted in Flatbush subwatershed, where 1.4 kilograms of Pontacyl Pink dye were injected into the Sainato Mine (Area 7) near RT9-9 on March 3, 1967. Sampling points RT6-9, RT6-23, RT6-26 in the Kittle run area and RT9-5 (Flatbush) were sampled daily and tested with the fluorometer. After several weeks of sampling, an inspection of the deep mine at the point of injection revealed the dye had settled to the bottom of a water impoundment located behind a roof fall. This incident is a good example of the effective damming of water within the mine by roof fall debris. Mine maps indicate that natural water movement would have been directed toward Kittle Run along the dominant West Fork of the Belington syncline.

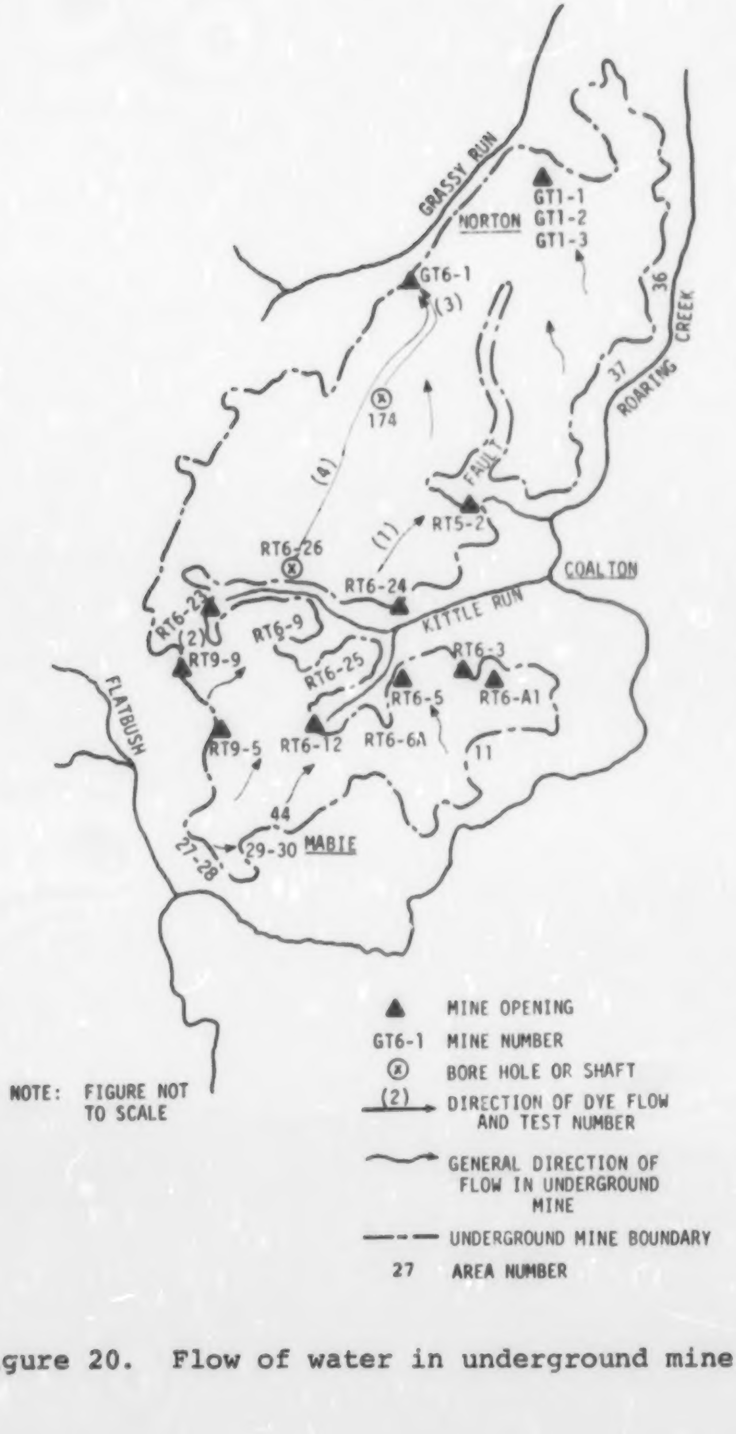

GRASSY RUN
NORTON
GT1-1
GT1-2
GT1-3
GT6-1
(3)
36
37
ROARING CREEK
174
(4)
FAULT
RT5-2
(1)
RT6-26
RT6-24
COALTON
KITTLE RUN
RT6-23
(2)
RT6-9
RT9-9
RT6-25
RT6-3
RT6-5
RT6-A1
FLATBUSH
RT9-5
RT6-12
RT6-6A
11
44
27-28
29-30
MABIE
MINE OPENING
GT6-1 MINE NUMBER
BORE HOLE OR SHAFT
(2) DIRECTION OF DYE FLOW AND TEST NUMBER
GENERAL DIRECTION OF FLOW IN UNDERGROUND MINE
UNDERGROUND MINE BOUNDARY
27 AREA NUMBER
NOTE: FIGURE NOT TO SCALE

Figure 20. Flow of water in underground mine.

On January 7, 1967, approximately 0.5 kilogram of Pontacyl Pink was dropped into a power shaft (Site 174) which penetrates the mine in the main heading and drainway about 854 meters from the mine opening on Grassy Run at GT6-1. On February 17, 2.3 kilogram of dye was injected into the same drainway through a deep mine shaft at RT6-26 in upper Kittle Run. The point of injection was about 2743 meters from GT6-1.

Sampling was at sites GT6-1, GT1-2, GT1-3, and RT5-2. On February 23 a dye trace was detected at GT6-1. This trace resulted from the first dye injection, which required 49 days to flow through the mine with an average speed of 17.4 meters per day.

On April 11, a dye discharge was detected at GT6-1, and peak dye concentration occurred on April 13 with fluorometric readings of 100 on the 300 X Scale. Thus, the second dye injection on Kittle Run required 53 days to reach Grassy Run, with an average flow of 51.8 meters per day.

During the dye sampling period, two major floods occurred in this section of the mine, moving directly down the West Fork of the Belington syncline. The slow rate of flows through the mine is attributed to water impoundments caused by roof falls resulting from robbing of pillars and eventually abandonment of the mined-out area.

Results of the drilling and tracer studies were used in conjunction with mine maps to formulate a picture of the groundwater movement in the Grassy Run-Roaring Creek watershed (Figure 20). Arrows on the map show the most probable directions of water movement within the underground mine.

Surface water flowed through strip mines located on the updip side of the coal seam in the Flatbush subwatershed and flowed into the intercepted underground mine. Part of the water eventually discharged through three portals in the Kittle Run subwatershed at RT6-23, RT6-9, and RT6-25. The rest of the mine water continued to flow through the main headings of the old mine below natural drainage, crossing under Kittle Run at RT6-26. The difference in elevation of these discharge points is due to a local dip in the coal seam. Water in the main heading continues to flow north down the drainway to GT6-1 in the Grassy Run watershed.

Extensive strip mining on both sides of Kittle Run resulted in water impoundments caused by overburden material placed in the center of the streambed. Mine water discharging at the surface from the three portals seeped through the refuse and eventually discharged near the mouth of the stream to form the west branch of Kittle Run, a tributary to Roaring Creek. This water flows into Roaring Creek at Coalton, West Virginia. Part of the water that seeped into the deep mine on the north side flowed through the mine and discharged into White's Run from mine portal RT5-2 (Figure 20).

LAND PERMITS

Responsibility for securing land permits for the project area was with the State of West Virginia. All land in the project area was under private ownership. The State retained a local attorney to determine ownership of the land, draw up permit agreements, obtain landowner signatures, and record the agreements.

A copy of the general agreement is presented in the appendices. Although the period of the agreement was to be for 10 years (1965-1975), the major landowner within the project area would agree only to 7 years. Thus, the project was geared to operate in that time frame.

The USBM assisted the State's lawyer in securing the agreements with landowners. The consideration granted the landowners under the basic agreement consisted of the benefits derived from strip mine reclamation and pollution abatement; the agreement did not include payments either in money or services. After nearly all the agreements had been signed, it was discovered that the form of the agreement was not valid. The agreement was rewritten to designate only the State as the permittee. When the revised agreement was presented for signatures many landowners who signed the original resisted signing the second document.

It was therefore necessary to negotiate with some of the landowners. Although no money was ever paid for an agreement, other considerations were granted. For two owners who heated their homes with coal from a strip mine to be reclaimed, it was agreed to mine them 1000 tons of coal and haul it to a designated place on the owner's land. Two owners required that a portion of a strip mine be left unreclaimed so that a future deep mine could be placed there. Two owners required that a barbed wire fence be constructed. One owner required gates with locks. Several owners required an agreement that unvegetated strip mines outside the project area would be planted and the performance bonds released by the State. Some owners never signed agreements.

Obtaining land permits was one of the most difficult and time-consuming aspects of the demonstration project. Negotiations with the major landowners continued over several months. Some properties were tied up in heirship with as many as 14 heirs in many locations in the United States.

SECTION 5

RECLAMATION AND REVEGETATION

PRELIMINARY PLANS FOR RECLAMATION AND REVEGETATION

Based on the mining, geology, hydrology, and water quality data on the project site, and on the reconnaissance survey, a preliminary reclamation guide was prepared. After review by the Technical Committee, a consulting firm was hired to prepare a final reclamation plan including specifications and a bid package. The project site was divided into 45 work areas, Figure 21. The details of each work area are presented in the Appendices.

The basic plan for reclamation was to prevent air and water from entering the underground workings. To accomplish this objective openings on the updip side were to be sealed with masonry blocks or clay seals and the surface mines graded to facilitate rapid movement of water away from the underground mine. Openings on the downdip side were to be sealed with "wet" seals. Subsidence areas over the mine site were to be filled.

Following is a list of specific control measures:

1) Air sealing of the underground mine was to be accomplished by filling all boreholes, subsidence holes, and other passages into the mine. "Wet" mine seals, which allow water to leave the mine, but prevent air from entering, were to be constructed at all openings discharging water. Air sealing should prevent oxygen from entering the mine, which would stop the oxidation of pyrite in the mine and reduce the production of iron and acidity.

2) Water diversion from the underground mine working was to be instituted. Water is the transport medium for carrying acid and iron from the mining environment. Therefore, water diversion would reduce the amount of water passing through a surface or underground mine, and thus reduce the amount of pollution. This was to be accomplished by filling subsidence holes, rechanneling streams to establish drainage away from the

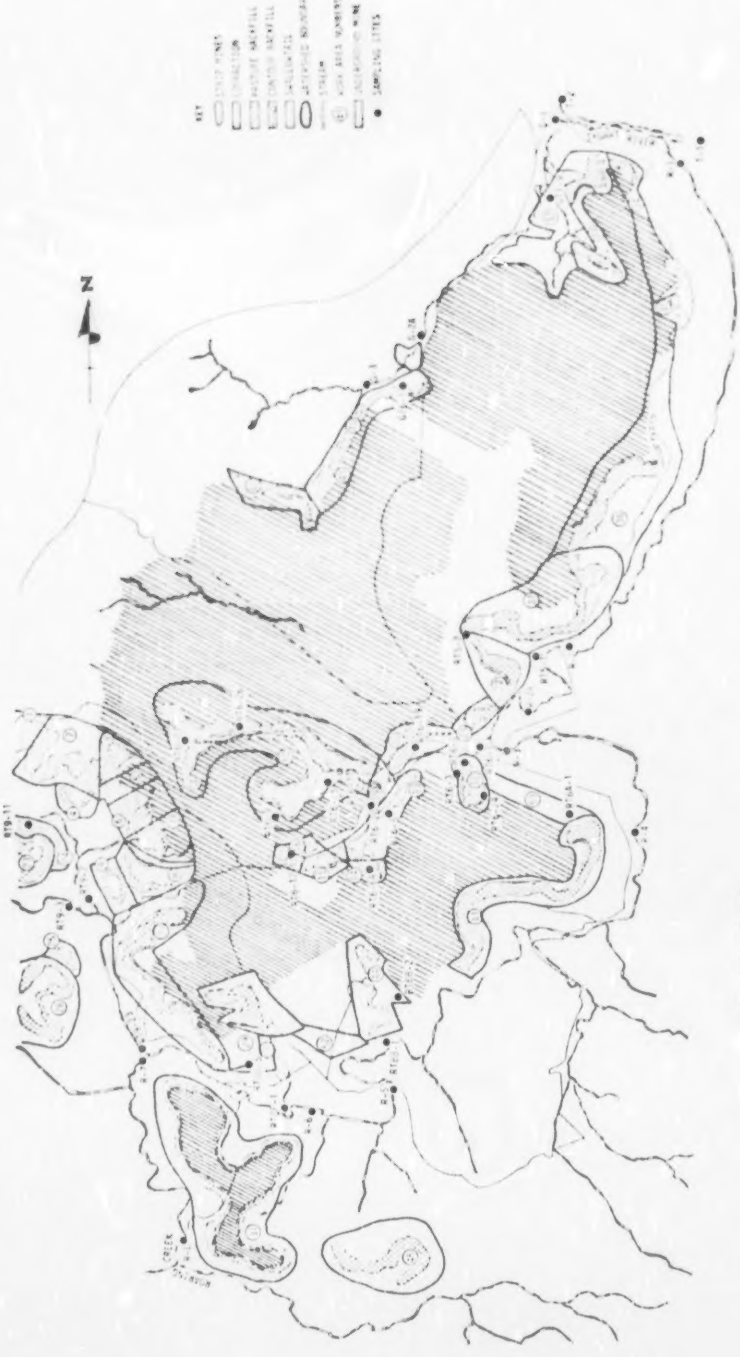

KEY
PASTURE BACKFILL
CONTOUR BACKFILL
WATERSHED BOUNDARY
STREAM
WORK AREA NUMBER
SAMPLING SITES
N
0 500 1000 FEET
(1 FOOT = 0.305 METERS)
CREEK

Figure 21. Location of work areas and sampling sites.

mines, and constructing solid "dry" seals in portals through which water could not pass.

3) Surface mine reclamation was to be performed by regrading strip mine areas to establish drainage away from the mining area and reduce the time in which water would be in contact with acid-producing materials. During regrading, the highly acid material was to be buried when possible.

4) Acid-producing spoils and refuse were to be buried whenever possible in surface mine pits to eliminate their major contribution to pollution.

5) All disturbed areas were to be revegetated to prevent erosion and stabilize the backfills.

RECLAMATION PROJECT

Reclamation Contract

As soon as the final designs were completed, a bidding package was prepared and advertised. Eleven bids were submitted. The original bid package was later revised, as were all bids, to include a more detailed cost breakdown and thus facilitate closer comparison of bids. A review board of selected experts rated the bids.

Since the extent of the mining was unknown and mine maps of the area were not totally reliable, bidders could not accurately itemize the exact extent and type of work required. For this reason, a fixed-price bid for the entire job was not feasible and bidding was on a cost-plus-fixed-fee basis. The bid was awarded to Franklin W. Peters and Associates at a value of $1,640,383. Average unit costs upon which the bid was made are shown in Table 18. The contract did not include filling and sealing the subsidence holes over the mine away from the highwall or revegetation of the reclaimed surface mines. The contract stipulated that all work be completed in 24 months (by July 1968). A team from the USBM supervised the construction contract and was responsible for verifying records concerning equipment usage, man hours, yardage, etc., and for approving the work performed.

TABLE 18. AVERAGE UNIT COSTS OF CONSTRUCTION BID

Common excavation	\$0.22/cubic yard[a]
Subsidence excavation	\$0.81/cubic yard
Compacted backfill	\$0.50/cubic yard

[a] To convert \$/cubic yard to \$/cubic meter multiply by 1.31.

Reclamation Procedures

Construction work was divided into three phases: (1) clearing and grubbing, (2) mine sealing, and (3) surface reclamation. It is emphasized that mine sealing and surface reclamation were mostly performed simultaneously. Revegatation was initiated after sealing and reclamation were completed. Plans and procedures for revegetation were outlined in a separate contract.

Clearing and Grubbing--

For clearing and grubbing, which required removal of all trees and roots, Model 977 Traxacavators served as root rakes. Suitable trees (10 centimeters in diameter, 30 centimeters above ground) were cut into saw logs and given to property owners as specified under land leasing agreements. All remnants were burned. All areas were cleared and grubbed prior to surface reclamation.

Mine Sealing--

Several types of seals, varying in structure and function, were constructed during the project. The seal types include:

- Dry Seal - The dry seal is constructed by placing suitable material in mine openings to prevent the entrance of air and water into the mine. This seal is suitable for openings where there is little or no flow and little danger of a hydrostatic head developing.
- Wet Seal - A wet seal prevents the entrance of air into a mine while allowing the normal mine discharge to flow through the seal. This seal is constructed with a water trap similar to traps in sinks and drains.
- Hydraulic Seal (clay seal) - Construction of a hydraulic seal involves placing a plug in a mine entrance discharging water. The plug prevents the discharge when the mine is flooded. Flooding excludes air from the mine and retards the oxidation of sulfide minerals.

Both "wet" and "dry" seals were constructed from two courses of fly ash blocks, which were coated with urethane foam on both sides to protect the blocks from acid attack. The mine openings were timbered on both sides of the seals to keep the weight of the roof off the seals. Dry seals consisted of one wall, whereas wet seals consisted of two or three walls. For the wet seals, one wall was solid except that two blocks were removed from the bottom to allow for the flow of water. Figures 22, 23, and 24 illustrate the design of a typical wet seal used during this study.

Where severe caving was observed and sites were unsuitable for masonry type seals, underground mine openings were sealed with clay. Clay was brought from borrow pits by pans and was compacted against the deteriorated openings by a vibrating "sheeps foot" (Figure 25). The compacted clay was installed approximately 0.5 meters above the openings. The height was determined by the degree of highwall fracturing.

Three air compressors and an air tract carrier for air hammer and pumping operations were used in underground seal construction. Seal site preparation was done with a small, maneuverable bulldozer.

Surface Reclamation--

Surface reclamation consisted largely of backfilling and burying of spoils. Eleven bulldozers were used to backfill and rough-grade the spoil. Final grading was accomplished with a 600 motor grader (rubber-tired), which was also used to maintain haul roads. A power shovel was used for stream channeling and to establish drainage. The shovel saw limited use during the project.

Three model 977 Traxcavators with front-mounted hi-lift buckets were used to explore the highwall face for buried mine openings. Four pans were employed for long haulage of spoil and for transfer of clay from borrow pits to clay compaction areas.

Backfills on the surface mines were of three types: contour, pasture, and swallowtail. For a contour backfill (Figures 26 and 27), the spoil was graded back as close as possible to the original contour of the land. Usually the top of the highwall was pushed down to complete the backfill. For a pasture backfill (Figures 28 and 29), the spoil was graded to form a small slope away from the highwall and the highwall was sound. The swallow-tail backfill (Figures 30 and 31), was similar to the pasture backfill except that a waterway was constructed parallel to the highwall. The waterway was located away from the highwall to allow water to drain over the outer slope at specified low points on the backfill. Where possible, soil low in acidity was hauled in and placed on top of the backfill to facilitate revegetation and reduce acid production. Most of the

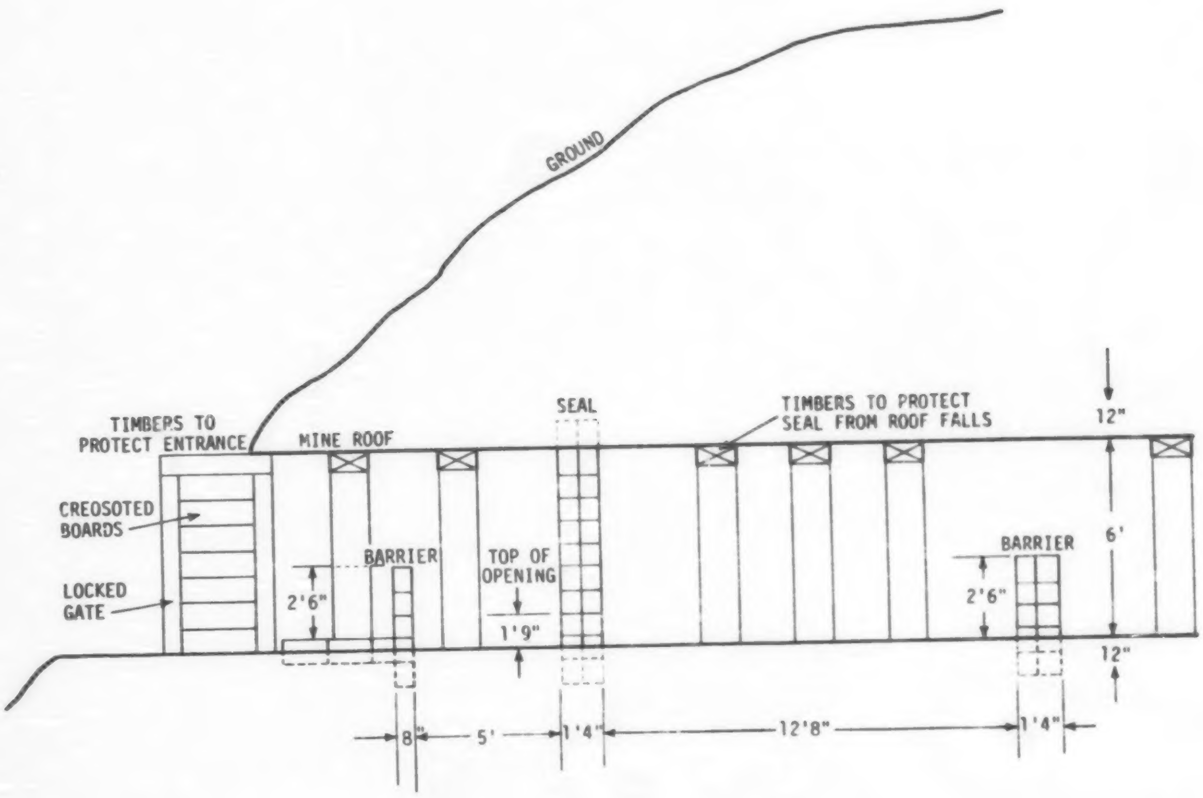

GROUND
TIMBERS TO PROTECT ENTRANCE
MINE ROOF
SEAL
TIMBERS TO PROTECT SEAL FROM ROOF FALLS
12"
CREOSOTED BOARDS
LOCKED GATE
2'6"
BARRIER
TOP OF OPENING
1'9"
BARRIER
2'6"
6'
12"
8"
5'
1'4"
12'8"
1'4"

Figure 22. Cross section of wet mine seal.[a]

[a] To convert inches to centimeters multiply by 2.54; to convert to feet to meters multiply by 0.305.

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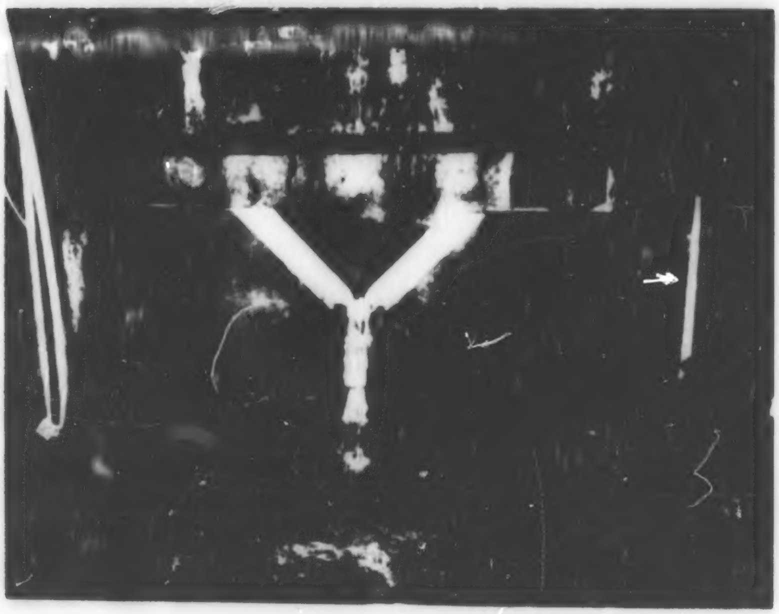

Figure 23. Wet seal at Site RT9-11 with weir to measure discharge rate and plastic pipe to draw off air samples from within mine.

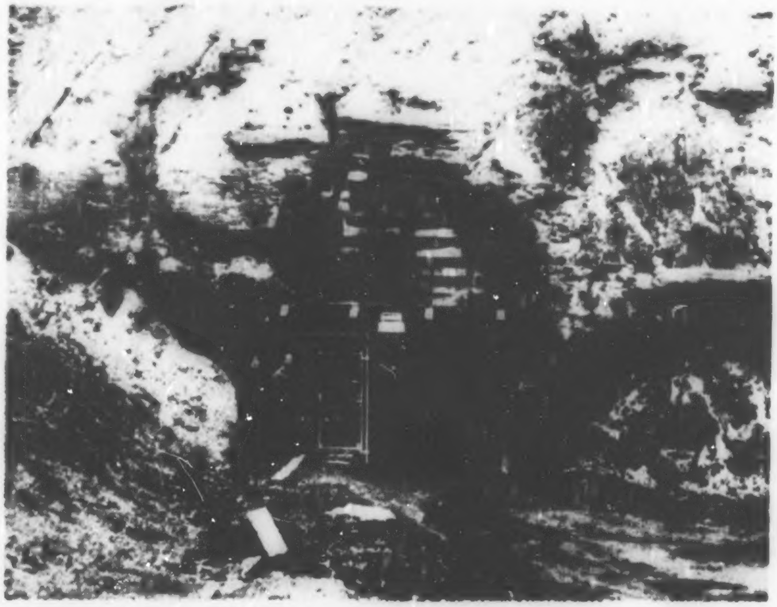

Figure 24. Wet seal from outside mine.

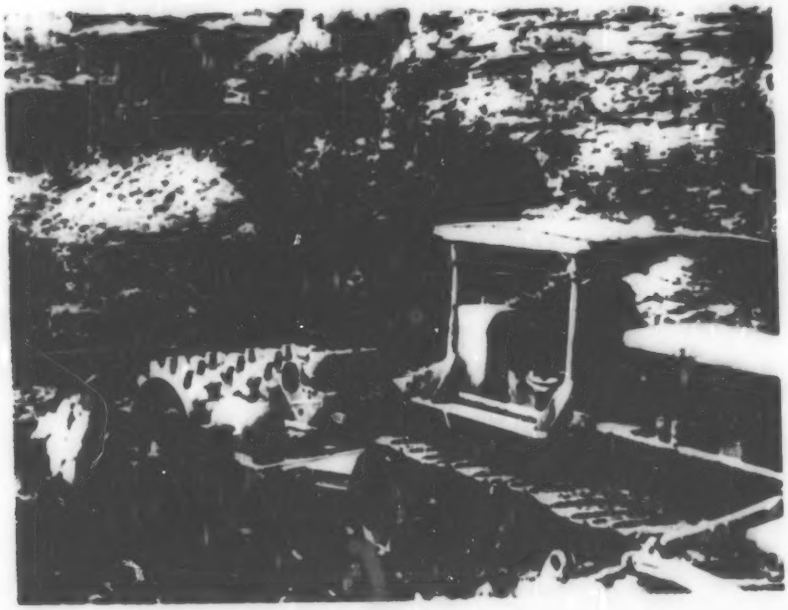

Figure 25. Construction of a compacted backfill with a vibrating "sheeps foot" compacter.

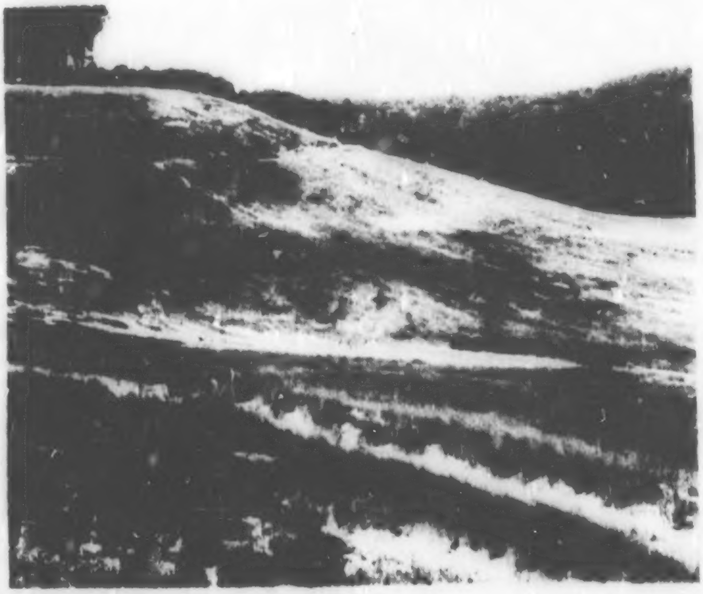

Figure 26. Contour backfill - Area 27.

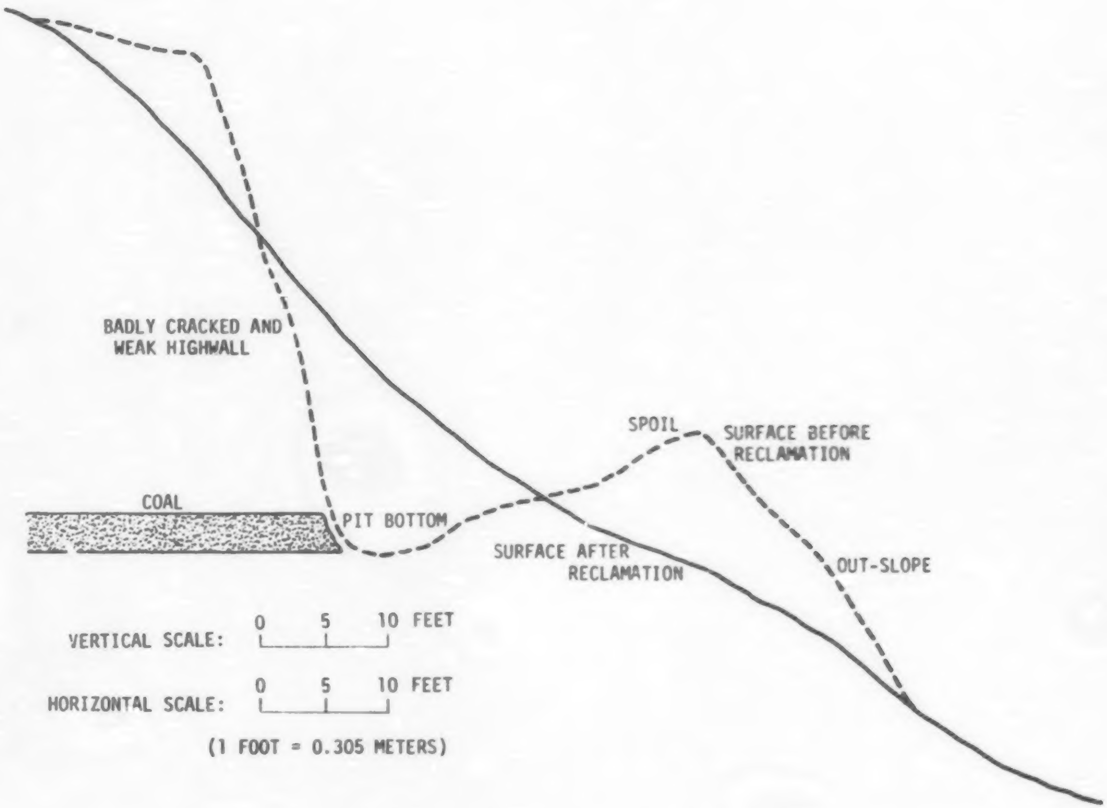
BADLY CRACKED AND
WEAK HIGHWALL
COAL
PIT BOTTOM
SPOIL
SURFACE BEFORE
RECLAMATION
SURFACE AFTER
RECLAMATION
OUT-SLOPE
VERTICAL SCALE: 0 5 10 FEET
HORIZONTAL SCALE: 0 5 10 FEET
(1 FOOT = 0.305 METERS)

Figure 27. Typical contour backfill.

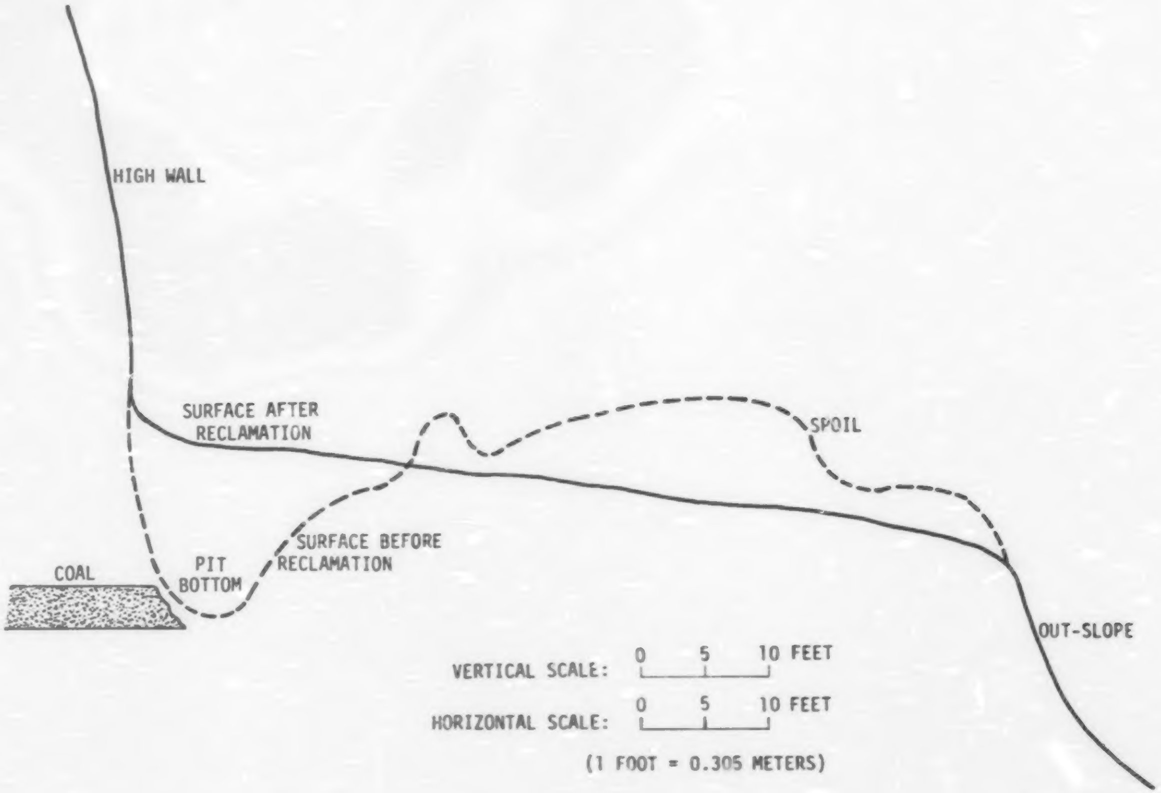
HIGH WALL
SURFACE AFTER RECLAMATION
SPOIL
COAL
PIT BOTTOM
SURFACE BEFORE RECLAMATION
OUT-SLOPE
VERTICAL SCALE: 0 5 10 FEET
HORIZONTAL SCALE: 0 5 10 FEET
(1 FOOT = 0.305 METERS)

Figure 28. Typical pasture backfill.

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Figure 29. Pasture backfill - Area 3.

Figure 30. Swallow-tail backfill - Area 2.

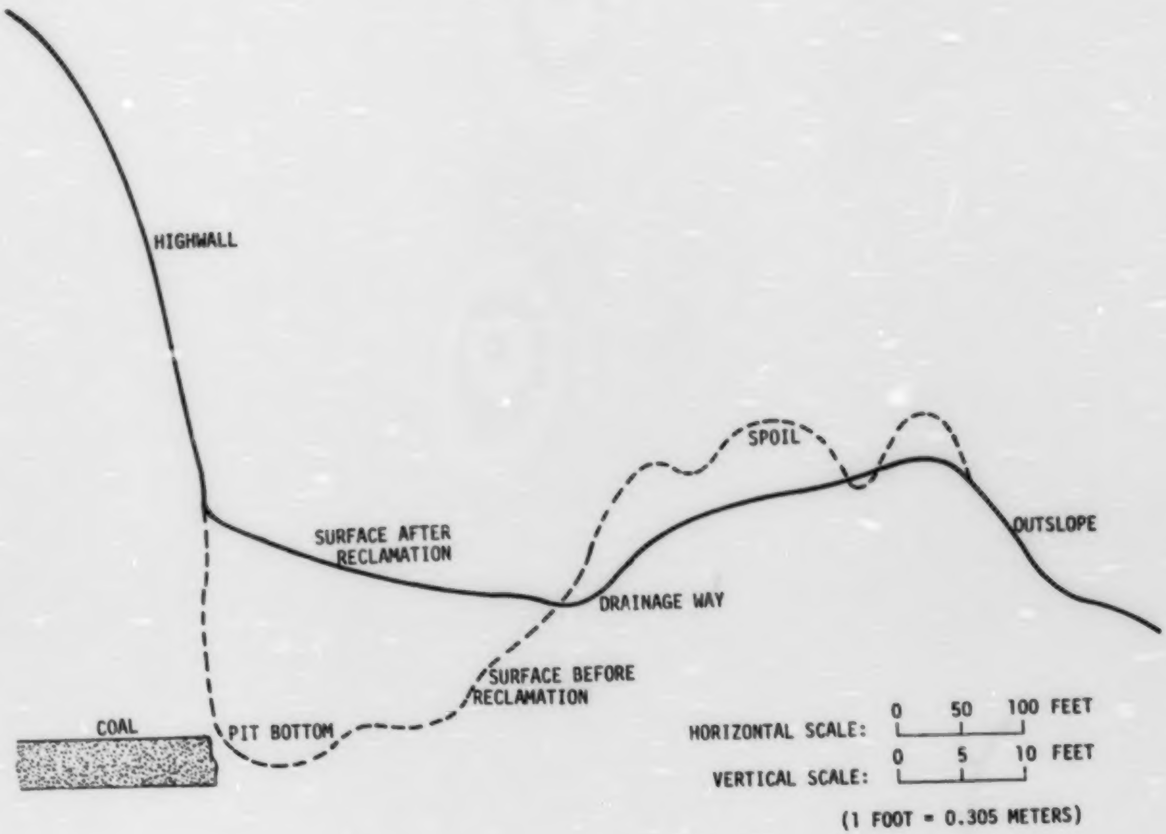
HIGHWALL
SPOIL
OUTSLOPE
SURFACE AFTER RECLAMATION
DRAINAGE WAY
SURFACE BEFORE RECLAMATION
COAL
PIT BOTTOM
HORIZONTAL SCALE: 0 50 100 FEET
VERTICAL SCALE: 0 5 10 FEET
(1 FOOT = 0.305 METERS)

Figure 31. Typical swallow-tail backfill.

subsidence holes within 30 meters of the highwall were filled with soil during backfilling. Approximately 17 percent of the total backfill material moved was used as fill for subsidence holes near the highwall.

Redefinition of Project Objectives--

As expected, conditions unknown prior to construction were revealed as construction progressed. Isolation and selective placement of toxic spoil required that much of the material be moved more than once, resulting in necessary but unforseen extra work. Also, numerous openings which did not appear on the mine maps were uncovered and required sealing. These additional efforts, along with bad weather during the winter of 1967, hampered progress on the reclamation project. By April 1967, it was anticipated that a cost overrun of the original bid amount would occur if the project were completed as originally designed. In August 1967, an order to terminate the project was given by FWPCA.

Because the original project objectives were to demonstrate and evaluate field applications of methods for at-source pollution control on a watershed basis, construction had not proceeded in an order that would be logical for a shorter-term project. For example, even though most of the wet seals (air seals) had been completed in areas where backfilling was performed, very little work had been done on subsidence. Therefore, evaluation of air sealing was not possible in subsided areas, since the mine atmosphere was directly exposed to the outside via subsidence.

Since the basis for evaluation was to have been the effect of reclamation on the entire watershed, only limited background data were available concerning the small subwatersheds that were affected by construction. In an attempt to gain maximum benefits from the construction work performed, emphasis was shifted to evaluation of individual watersheds. The remaining work was tailored to complete some degree of reclamation in the areas where most of the construction had been done.

Redefinition of project objectives was stated in the termination specification as follows:

> "The purpose.... is to finish off the project as soon and as economically as possible and at the same time retain and augment to the maximum extent possible such water quality benefits as may be derived from work thus far completed. The work specified herein (final work to be done) is pointed primarily toward measuring the benefits from the reclamation areas of strip mining rather than, as in the case heretofore, measuring the benefits of water diversions from the deep mines derived from reclamation of surrounding strip mines and correction of areas of subsidence."

Thus, use of contour backfill for badly fractured highwalls, sealing of subsidence, and installation of wet seals were eliminated by the termination order.

By November 1967, construction required for termination of the project was completed. Practically all the work was performed on the south half (updip side) of the major underground mine (south half of Roaring Creek watershed). Reclamation was not performed in either the Grassy Run watershed or north of Coalton, W. Va., in the Roaring Creek watershed. The work completed in each subwatershed is reported in the Appendix. In 16 months, Franklin W. Peters and Associates had employed, during peak periods, 40 men and 26 pieces of heavy equipment. Reclamation work performed is summarized in Table 19.

As a result of the redefined plans the major underground mine was not air-sealed. A small isolated mine was sealed, however, and was available for evaluation. Thus, any improvement in water quality would occur only in the south portion of the Roaring Creek watershed in which the sealed mine was located. The effectiveness of air sealing and water diversion on this smaller mine might thus be determined.

REVEGETATION PROJECT

Revegetation Contract

In September 1967, a contract in the amount of $205,911 was awarded to the Tygart Valley Soil Conservation District (TVSCD) on a cost-reimbursable basis to revegetate the reclaimed work areas. The cost-reimbursible contract was appropriate since TVSCD had revegetated most of the surface mines in the area and was a nonprofit organization.

Revegetation Procedures

Soil Sampling--

Areas to be revegetated were divided into 10-acre plots for soil sampling, which served as a guide to selection of vegetation and to fertilizer and lime requirements. Twenty samples were taken in each 10-acre plot. Specific conductance and pH were determined on individual samples, then the samples were mixed for determination of pH, specific conductance, exchange acid, sulfate, phosphorus, and nitrogen. Some composites were also analyzed for potassium, sodium, iron, aluminum, and manganese content. Analytical procedures are described in the Appendix.

The value obtained for exchange acid was used to determine lime requirements for treating the top 15 centimeters of soil. A minimum of 1.8 tonnes of agricultural limestone was applied to all areas. The procedure outlined by Black, et al, (14) was

TABLE 19. RECLAMATION WORK PERFORMED

Reclamation	
Surface mines reclaimed	12.5 miles[a] (650 acres)[b]
Backfill, total	3.6 million cubic yards
Subsidence holes filled	450
Mine seals, total	101
Mine seal, dry	43
Mine seal, wet	12
Mine seal, clay	41
Mine seal, other	5
Revegetation, total	610 acres
Grass planted only	322 acres
Grass hydroseeded only	16 acres
Trees planted only	57 acres
Grass hydroseeded and trees planted	195 acres
Grass and trees planted	120 acres

[a] To convert miles to kilometers, multiply by 1.609.
[b] To convert acres to hectares, multiply by 0.405.

used. Fertility of the spoil material was found to be low, and a standard fertilizer application of 0.45 tonne of 10-10-10 per 0.4 hectare was applied to all areas.

Types of Flora Planted--

The planting operation was based on need to develop a rapid cover on the backfills to prevent erosion and water pollution. Thus, grass was to be planted on all areas. Areas with steep slopes and those containing the more toxic materials were to be overplanted with trees.

After contact with various Federal and state agencies for recommendations and results obtained from a USFS study on Rich Mountain, the species of trees, grasses, and legumes to be planted were selected. The species shown in Table 20 were chosen. Two special grass seeds were acquired that were reported to be resistant to toxicity from aluminum and/or manganese, which were present in some spoil materials. One was a barley developed in Canada and the other a rye grass developed in Belgium. One ton of each was imported and planted.

The seed mixtures in all but a few cases contained a legume and several grasses. Sericea lespedeza was the most commonly used legume because of its earlier successful application in surface mine planting. Birdsfoot trefoil was the other predominant legume. Various combinations of grasses and legumes were seeded, as reported in Table 21.

Planting Methods--

Planting was done by conventional methods and hydroseeding. In conventional planting, lime and fertilizer were applied from bulk trucks (Figure 32). On steeper slopes these materials were sometimes applied from agricultural fertilizer spreaders pulled by farm or crawler tractors (Figure 33). These materials were then worked into the soil with a spike-tooth harrow. Grass seed was then planted with a grain drill. These conventional methods were used on all areas that were not too steep for tractors.

Hydroseeding was done on the steep areas and along water courses. After application of lime in the conventional manner, the hydroseeder sprayed a mixture of grass seed, fertilizer, and mulch.* The material was not worked into the soil. In some areas, black locust seeds were also hydroseeded.

In Area 37, "frost" seeding was performed. Lime was applied in October, and grass seed was broadcast on the surface of the frozen ground the following March. Frost seeding is

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* Metroganic 100 mulch was applied at a rate of 1 ton per acre. This is a composited garbage material containing some trace elements and fertilizer value. It costs about half as much as wood fiber mulch.

TABLE 20. SPECIES OF PLANTS USED FOR REVEGETATION

Grasses	Legumes	Trees[d]
Tall fescue	Sericea lespedeza	Scotch pine
Tall oat grass	Birdsfoot trefoil	Shortleaf pine
Weeping love grass	Alsike clover	Virginia pine
Orchard grass	Sweet clover	White pine
Kentucky bluegrass[a]		European black alder
Perennial rye grass		Cottonwood
Reed canary grass		Japanese larch
Canadian barley[b]		Tulip poplar
Belgium rye grass[c]		White oak
		Black locust

[a] Common strain.

[b] Charlottetown 80 barley obtained from Canada, Dept. of Agriculture. Has resistance to aluminum toxicity.

[c] RVP Malli rye grass imported from Belgium. Reported to be resistant to aluminum and manganese toxicity.

[d] All trees except black locust were planted as seedlings; black locust seeds were hydroseeded.

TABLE 21. SEED MIXTURES PLANTED (lb/acre)[a]

AREA 1, 2, 3, & 5 B. Rye grass - 5 S. Lespedeza - 15 T. Fescue - 10 T. Oat grass - 10 C. Barley - 5	**AREA 4** W. Love grass - 7 Orchard grass - 7 B. Trefoil - 15	**AREA 6, 7, 8, & 9** W. Love grass - 10 Orchard grass - 3 K. Bluegrass - 10 B. Trefoil - 10 Alside Clover - 2	**AREA 10** S. Lespedeza - 10 W. Love grass - 5 K. Bluegrass - 5 T. Fescue - 5 P. Rye grass - 10
AREA 11 B. Trefoil - 18 Sweet Clover - 5 T. Fescue - 10 K. Bluegrass - 8 R. Canary grass - 1	**AREA 12** K. Bluegrass - 8 B. Trefoil - 13 P. Rye grass - 3 T. Fescue - 3	**AREA 13 & 19** S. Lespedeza - 20 T. Fescue - 15 T. Oat grass - 15	**AREA 14** S. Lespedeza - 10 T. Fescue - 15 T. Oat grass - 10
AREA 15 - 19 S. Lespedeza - 15 T. Fescue - 15 T. Oat grass - 15	**AREA 20** S. Lespedeza - 10 W. Love grass - 5 Orchard grass - 5 K. Bluegrass - 10	**AREA 23 & 24** S. Lespedeza - 10 B. Rye grass - 15 W. Love grass - 10 C. Barley - 15	**AREA 27** B. Trefoil - 10 W. Love grass - 10 T. Fescue - 15
AREA 28 - 30 S. Lespedeza - 15 T. Fescue - 10 T. Oat grass - 10 W. Love grass - 5 K. Bluegrass - 5	**AREA 36** T. Fescue - 11 P. Rye grass - 9 W. Love grass - 4 Alsike Clover - 1	**AREA 37** B. Trefoil - 10 Orchard grass - 10 K. Bluegrass - 10 Sweet Clover - 5	**AREA 44 (Hydroseeded)** S. Lespedeza - 10 W. Love grass - 5 K. Bluegrass - 10 Orchard grass - 5
AREA 44 (Conventional plant) T. Fescue - 4 K. Bluegrass - 24 S. Lespedeza - 4 Orchard grass - 5			

[a] To convert lbs/acre to kilomgrams/hectare multiply by 1.11

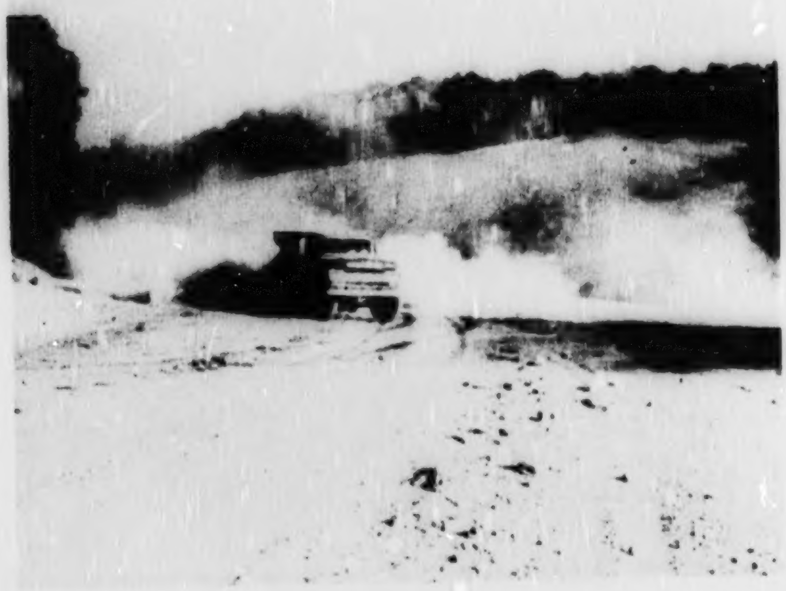

Figure 32. Liming from bulk truck - Area 8.

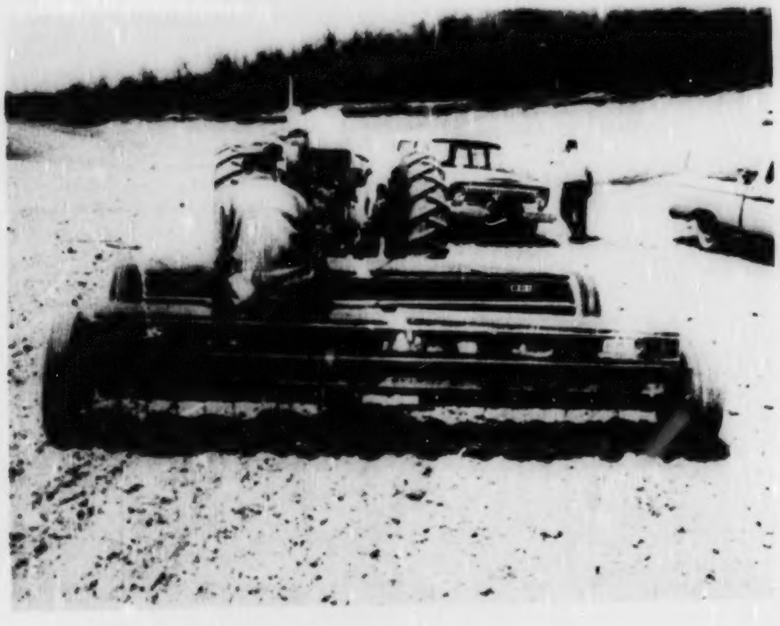

Figure 33. Seeding and fertilizing - Area 29.

based on the theory that freezing and thawing of the soil surface will work the seed into the ground and the seed will have an early start over those seeds planted at a later date. The area was top-dressed with fertilizer in May.

Trees were selected on the basis of earlier success on surface mine spoils and availability. European black alder was chosen as the base tree because of its reported good growth under acid conditions and its nitrogen-fixing ability. Two basic tree mixtures were planted (Table 22), one all deciduous and one including conifers. The deciduous plantings consisted of three rows of black alder followed by a row each of cottonwood, tulip poplar and white oak. In the conifer plantings, three rows of black alder were followed by three rows of a grab mix of pines. Trees were planted 2 meters apart in rows approximately 2 meters apart. In a few areas, no black alders were planted and black locust was hydroseeded.

TABLE 22. TREE MIXTURES PLANTED

Pine mix	Deciduous mix
Scotch pine	European black alder
Shortleaf pine	Cottonwood
Virginia pine	Tulip poplar
White pine	White oak

COST OF RECLAMATION AND REVEGETATION

Cost Analysis Procedures: Reclamation

The reclamation contract was entered into on June 30, 1966, at an estimated cost of $1,640,382. This contract did not include revegetation or the filling of subsidence holes beyond 30.5 meters from the highwall. Because of the many unknown conditions anticipated in the heavily mined-out areas, the contract was on a cost-plus, fixed-fee basis.

The contractor kept daily records of labor and equipment for each work area in the project. Table 23 shows cost analyses breakdown for (A) clearing and grubbing (B) reclamation operation, and (C) underground operation. These data were later entered on computer cards, and a computer program was developed to obtain the desired cost breakdown.

Indirect Costs--

Indirect costs included everthing not directly applied to the work areas, such as office work and supplies. These costs were distributed among the various work areas proportionally to

TABLE 23. COST ANALYSIS BREAKDOWN

A. Clearing and Grubbing

1. Cutting and clearing
2. Grubbing and clearing
3. Cutting landowner's timber
4. Handling landowner's timber
5. Chipping and hauling
6. Fire detail
7. Root rake hauling
8. Access road grading
9. Cleaning pits and pit mouth entry
10. Drainage grading
11. Downtime
12. Reporting time
13. Routine maintenance

B. Reclamation Operation

1. Cleaning pit
2. Cleaning face of highwall
3. Scraping SL from soilback
4. Backfilling
    a) Pasture
    b) Contour
    c) Swallow-tail
5. Compaction
6. Subsidence
    a) Drilling and shooting
    b) Hauling material
    c) Bull dozing
    d) Shovel
7. Moving equipment to area
8. Drainage, structure grading
9. Grading work sites
10. Drainage grading
11. Downtime
12. Reporting time
13. Maintenance
14. Grading roads
15. Cleanup of garbage
16. Ditching
17. Borrow pit
18. Carbonaceous material
    a) Hauling
    b) Burying
    c) Bulldozing

C. Underground Operation

1. Cleaning and temporary timbering
2. Removal temporary timber and ribs at seal location
3. Concrete footer seal location
4. Provide hitches in roof and ribs at seal location
5. Erect seal
6. Coat seal inbye side with bitumastic
7. Seal perimeter with urethane foam
8. Install rigid plastic tubing
9. Pumping operation
10. Ventilation
11. Downtime
12. Reporting time
13. Routine maintenance
14. Hauling material and supplies to work sites
15. Dismantling and assembling equipment
16. Drilling, blasting, etc.

direct costs. For example, if 10 percent of the direct costs was charged to Area 2, then 10 percent of the indirect costs was also charged to that area.

Approximately 260 hectares of surface mine were reclaimed under the reclamation contract. For estimating and reporting costs by area reclaimed and volume of soil moved during reclamation, standard procedures were developed and followed. Aerial photographs of the project area taken during the planning stage were used to develop contour maps showing the finished grades, acreage, and cubic yards of earthen material to be moved for specified types of backfill on the work areas. Upon completion of the contract, a land survey was made of each work area to determine the total acreage and cubic yards of material moved.

Accuracy of the backfilling quantities is somewhat inexact because some backfill material was moved two or three times in an attempt to isolate the toxic spoil and bury it in the strip pit.

Cost Analysis Procedures: Revegetation

The revegetation contract amounting to $205,911 was awarded on a cost-reimbursable basis in September 1967. In the spring of 1968 approximately 284 hectares* of land disturbed during reclamation were revegetated. Because the contractor completed revegetation of the project in one growing season instead of two as originally planned, cost for revegetation was reduced to $177,727.

Since the contract required a detailed cost analysis, the contractor maintained accurate and complete records of all phases of work as it progressed. Labor and equipment hours for each work area were recorded daily, as were quanitites of lime and fertilizer applied and plantings of grass and trees. The daily records also included method of application, for example, truck spreading or box spreading of fertilizer and conventional seeding or hydroseeding of grasses. Species of grass seed and tree seedlings planted in each work area were recorded also.

Data were summarized monthly, with cumulative totals of labor, equipment, and materials applied to each work area. Foremen's time and overhead costs were distributed to the work areas in proportion to direct labor hours during the month. Distribution of vehicle rental costs was based on recorded hours of equipment use in each work area.

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* Hectares revegetated is higher than hectares reclaimed, because certain areas did not require reclamation before planting.

Costs Of Reclamation And Revegetation

Costs of surface mine reclamation, mine sealing, and revegetation are presented in various ways in this report for purposes of estimating cost of future reclamation work. An average overall cost, including both direct and indirect charges, is calculated for surface reclamation and mine sealing. Data are presented in Tables 24 to 30. Since direct costs (labor, equipment usage, and material) will vary on different reclamation projects depending on the condition and location of unreclaimed area, certain work areas on this project that involve a variety of working conditions and types of backfill and seals were selected for a special cost study. Data from this study are presented in Tables 31 and 32. All data from the selected work areas (SWA) will be designated.

Costs for these selected areas are shown two ways: (1) costs without clearing and grubbing, to show costs of reclaiming recently mined, unrevegetated areas that would require no clearing and grubbing and that could be reclaimed to satisfy most current state mine laws, and (2) costs including clearing and grubbing, to show costs of reclaiming old, abandoned strip mine areas overgrown with vegetation that would require clearing and grubbing prior to reclamation.

Since equipment rental was a main item of expense (40% of the total cost) in reclamation work, equipment costs were analyzed to determine the best and most economical equipment utilization for each type of work.

Equipment Costs--

During the period of the reclamation contract, the contractor leased 26 pieces of equipment on a monthly basis for use in reclamation work. The lessor was to be notified by letter 30 days prior to terminating the lease on any of the equipment.

The equipment used during reclamation, showing work hours, costs per hour, and range of cost per hour for each type of unit, are shown in Table 24.

Range of cost varied considerably for the bulldozers because the need to keep certain ones on rental during periods of adverse weather. For example, the bulldozer showing highest cost per hour ($79.86) was on rental during 4 winter months but, because of bad weather, was utilized only 144 hours during the rental period. If this equipment had not been kept on rental, the lessor would have moved it from the project, making it unavailable for spring operations.

The LeRoi air compressor was rented for 1 month, but after only 16 hours of use it was found to be insufficient for the

TABLE 24. RECLAMATION PROJECT COST BREAKDOWN, SUMMARY OF EQUIPMENT TIME

Type equipment	No. of pieces	Work hr	Total cost, $	Average cost per hr, $	Range in cost per hr, $
600 motor grader	1	481	10,385	21.59	0
TD-25 dozer	2	2,678	29,636	11.06	7.47-17.14
D-7 dozer	1	2,492	28,259	11.34	0
D-8 dozer	2	2,851	28,358	9.94	8.50-10.31
D-9 dozer	6	10,859	237,360	21.86	12.63-79.86
Koechring shovel	1	951	23,024	24.21	0
Compactor	1	560	16,100	28.75	0
977 Traxcavator	3	5,615	63,315	11.27	7.71-16.97
DW-21 pan	2	3,818	55,883	14.64	14.30-14.99
Scraper pan	2	1,048	25,195	24.04	11.81-30.55
John Deere crawler	1	1,892	4,162	2.20	0
Air tract carrier and attachments	1	396	10,363	26.17	0
Compressor	2	2,294	17,478	7.61	6.27-8.94
105 LeRoi air compressor	1	16	1,600	100.00	0
TOTAL	26	35,951	551,118		

job; therefore the average cost was extremely high at $100.00 per hour.

The 977 Traxcavators were used as hi-lifts to explore the strip pits for buried deep mine openings and as root rakes to clear areas prior to backfilling. Difficulty in using this equipment during winter months resulted in considerable variation in the cost per hour, as shown in Table 24.

The power shovel, operated at an average cost of $24.21 per hour, was used for stream channeling and establishing drainage from work areas. In February 1967 the shovel was damaged by a falling highwall and was down for repairs for the remainder of the project.

The scraper pans had limited use, mostly in work areas requiring compacted backfill.

The grader was used exclusively to maintain haulage roads, at an average cost of $21.59 per hour. The compressor, air tract, and crawler were used mostly for underground work pertaining to masonry seals.

Clearing and Grubbing Costs--

The first work performed on the project was the clearing of areas covered with volunteer trees and other vegetation established over the 25 years since stripping. This preparation of the land for the backfilling and sealing operations was designated as "Clearing and Grubbing," consisting of the following:

1) Trees with diameters less than 10 cm. measured 30 cm. from the ground, were uprooted, cut, and burned.

2) Trees with diameters greater than 10 cm. were cut, trimmed to saw log lengths, and stockpiled at a convenient location for the property owner.

3) Stumps and brush were uprooted and burned.

4) Boulders and rocks large enough to impede revegetation were buried in the spoil near the outer slope.

Average overall cost for clearing and grubbing was $134 per hectare or 16.6 percent of the total cost for surface mine reclamation (excluding revegetation). An average of 13 labor hours per hectare was required to clear and grub (Table 25). These costs, higher than originally estimated, were partially due to density of the forest in some areas and extra handling to cut pulpwood for the landowners. Average direct costs for selected work areas (SWA) varied considerably with respect to type of backfill performed in the work areas. For example (Table 31), the average costs per hectare for clearing and

TABLE 25. CLEARING AND GRUBBING COSTS FOR 651 ACRES[a]

	Cost, $	Hours
Direct labor, total	72,662	21,468
Direct labor, average per acre	112	32
Equipment, total	38,329	3,461
Equipment, average per acre	59	53
Direct cost, total	110,991	--
Indirect cost, total	103,518	--
Total cost	214,509	--
Average cost per acre	330	--

[a] To convert $/acre to $/hectare multiply by 2.47.

TABLE 26. COST OF 55 MASONRY SEALS

	Cost, $	Hours
Direct labor, total	65,949	17,932
Direct labor, average per seal	1,199	326
Equipment, total	50,729	5,602
Equipment, average per seal	922	101
Direct cost, total	116,678	--
Direct cost per seal	2,121	--
Indirect cost, total	110,913	--
Total cost	227,591	--
Average cost per seal	4,138	--

grubbing prior to contour backfilling on Areas 27, 28, and 44 were quite high, ranging from $51 to $149 per hectare. High costs were incurred in areas containing a fractured highwall. An unsafe portion of the highwall had to be cleared so that it could be pulled down. Also the material was needed for fill. Generally, costs were low in pasture and swallowtail backfill operations and in stripped areas where toxic spoil had prevented dense foliage and where vegetation on the highwall could be left undisturbed.

Mine Sealing Costs--

Forty-three masonry seals and twelve wet seals were constructed in the entries to abandoned drift mines at an average cost of $4138 per seal (Table 26).

High equipment cost was attributed to the exploration of the strip pit to locate mine openings and to clearing of debris from openings at the face of the highwall. Preparation for sealing, such as timbering and clearing debris from the seal site in the mine, was performed manually.

The average direct cost (SWA) for dry seals and wet seals are presented in Table 32, which shows that the wet seals cost about twice as much as dry seals. Cost of the dry seal on Work Area 8 was considerably higher than cost of other seals because of labor involved in opening and timbering the portal prior to constructing the seal.

In areas where the highwall was badly fractured and the stripping operation had intercepted the deep mine workings, openings were sealed by compacting clay against the openings and the highwall with a vibrating sheep's-foot. Although 41 openings were sealed this way, data were recorded only for Work Areas 19 and 10. These data are summarized in Table 27. The cost per seal in Work Area 10 was higher than that in Area 19 because of haulage from the borrow pit to the seal site.

Surface Mine Reclamation Costs--

The average cost of surface mine reclamation was $671 per hectare. Cost of moving earth was $0.27 per cubic meter (Table 28). These costs are higher than those reported by the U.S. Bureau of Mines for surface mine reclamation at Moraine State Park in Pennsylvania (15). Lower costs in some Pennsylvania cases may result from using state equipment and not allocating actual cost to the project. In their report, the costs per hectare for two areas were $316 and $567. The average earthmoving cost was $0.12 per cubic meter. Labor hours, 16 per hectare, were the same for both projects.

TABLE 27. CLAY COMPACTED SEALS

Work area	No. of seals	Cu. yd compacted backfill	Total cost, $	Cost per seal, $	Average cu. yd per seal[a]	Cost per cu. yd. $[b]
19	10	10,490	9,500	950	1,040	0.91
10	6	11,670	14,160	2,360	1,945	1.21

[a] To convert cu. yds. to cu. meters multiply by 0.76.

[b] To convert $/cu. yds. to $/cu. meters multiply by 1.31.

TABLE 28. SURFACE MINE RECLAMATION COSTS FOR 651 ACRES,[a] 3,060,000 Cu. Yd. MOVED[b]

	Cost, $	Hr.
Direct labor, total	96,884	25,558
Direct labor, average per acre	149	39
Equipment total	457,706	26,028
Equipment, average per acre	703	40
Direct cost, total	554,590	
Direct cost, average per acre	852	
Direct cost, average per cu. yd.	0.18	
Indirect cost, total	524,984	
Total cost	1,079,574	
Average cost per acre	1,658	
Average cost per cu. yd.	0.35	

[a] To convert $/acre to $/hectare multiply by 2.47.

[b] To convert $/cu.yd. to $/cu. meter multiply by 1.31

The average direct cost (SWA) for surface mine reclamation ranged from a low of $191 per hectare on contour backfill to a high of $475 per hectare for a combination of pasture-contour backfill (Table 31).

Average direct cost (SWA) per acre for pasture backfill reclamation was higher than for contour backfill, an unexpected result. Further studies showed that, in general, the spoil in the pasture backfill areas was more highly toxic than in the contour areas. Because this toxic spoil had to be moved several times, the costs were higher.

Because of additional earth work, swallow-tailed backfill was slightly more costly than pasture backfill.

High costs for all phases of reclamation involving a combination of pasture and contour backfill are due to complex problems in these work areas, including these six conditions:

1) Unknown interconnections between the strip and underground mines made it necessary to spend considerable time opening up the pit to locate fractures and openings into the underground mine.

2) The contractor was required to separate the toxic spoil from the nontoxic backfill material where feasible and bury the toxic material in the strip pit. This entailed moving the material two or three times in some areas. As a result, the amount of earth actually moved greatly exceeded the 2,339,535 cubic meters determined from before and after cross sections.

3) Approximately 17 percent of the total backfill material moved was used to fill subsidence holes on top of the highwall and as clay-compacted material for seals.

4) In many work areas it was necessary to establish drainage by rechanneling streams from strip mines prior to reclamation.

5) Adverse weather conditions during the winter months hampered the reclamation work project and necessitated payment of rent on equipment that was not in use.

6) In many areas, the highwall was fractured to the extent that it could not be left standing. In these places the wall was pulled down and the material used to complete the backfill.

Revegetation Costs--
The overall costs for revegetating the reclaimed work areas are summarized in Table 29. Average direct cost was $81 per hectare and total cost was $100 per hectare.

Costs varied considerably with type of revegetation. Costs were higher in steep areas which required use of a hydroseeder (Table 30). The hydroseeder also increased cost (SWA) in contour backfill areas (Table 31). The more level areas on which conventional equipment could be used were revegetated at a much lower cost.

TABLE 29. REVEGETATION COST FOR 709 ACRES[a]

	Cost, $	Hour
Direct labor, total	31,860	9,539
Direct labor, average per acre	45	14
Equipment, total	17,493	4,365
Equipment, average per acre	25	6
Material cost	45,190	
Hydroseeding contract cost	47,475	
Direct cost, total	142,018	
Direct cost, average per acre	200	
Indirect cost, total	33,709	
Total cost	175,727	
Total average cost per acre	248	

[a] To convert $/acre to $/hectare multiply by 2.47.

TABLE 30. COST BREAKDOWN OF REVEGETATION,[a] DOLLARS PER ACRE[b]

	Labor	Equipment	Material[c]	Indirect cost[d]	Total
Conventional grass[e]	32.65	36.51	63.39	32.07	164.62
Hydroseeding only[f]	18.23	227.32[a]	61.44	71.49	378.48
Trees only[g]	39.51	4.20	18.87	21.63	84.21
Hydroseeding, plus trees[h]	54.47	238.74[a]	76.78	84.93	454.92
Conventional grass[i], plus trees	68.53	23.29	64.80	37.22	193.84

[a] Hydroseeding work was subcontracted for $225 per acre which included mulch at one ton per acre.

[b] To convert $/acre to $/hectare multiply by 2.47.

[c] Includes lime, fertilizer, seed, and trees. In some "trees only" areas no fertilizer and/or lime were used.

[d] Indirect cost distributed on basis of direct cost.

[e] Fertilizer (0.5 ton per acre of 10-10-10), lime (2-4 tons per acre) applied from truck, grass planted by seeder box.

[f] Lime (2-4 tons per acre) spread from truck or from farm type fertilizer spreader, hydraulic application of grass seed, fertilizer (0.5 ton per acre 10-10-10).

[g] Hand-planted (900-1000 per acre).

[h] Hydroseeding plus hand-planted trees (900-1000 per acre).

[i] Conventional grass as in e, plus hand-planted trees (900 - 1000 per acre).

TABLE 31. DIRECT COST OF SURFACE RECLAMATION BY VARIOUS METHODS ON SELECTED WORK AREAS (SWA)

Work area no.	Acres[a]	Type of backfill	Cost per acre, reclamation, $	Type seeding[b]	Cost per acre, reclamation + seeding, $	Cost per acre, reclamation + seeding + clearing and grubbing, $
3	11.9	Pasture	383	C.H.	533	576
4	4.7	Pasture	56	C	140	174
5	4.3	Pasture	995	C	1,126	1,137
8	7.9	Pasture	740	C	840	1,035
9	11.7	Pasture	432	C	523	559
37	13.0	Pasture	798	C.H.	912	1,028
Mean	53.5		568		682	760
23,24	77.9	Contour	429	C.H.T.	669	704
28	11.0	Contour	265	C.H.T.	612	882
27	68.0	Contour	540	C.H.	907	1,275
29,30	37.7	Contour	542	C.H.T.	744	804
44	26.7	Contour	410	C.H.T.	684	812
Mean	221.3		472		754	918
1	18.7	Swallowtail	315	C.H.T.	546	566
2	40.3	Swallowtail	706	C.H.T.	815	843
Mean	59.0		582		730	755
10	140.3	Pasture and contour	1,060	C.H.T.	1,236	1,425
11	47.0	Pasture and contour	1,341	C	1,498	1,548
Mean	187.3		1,131		1,302	1,456

[a] To convert acres to hectares multiply by 0.405.

[b] Type seeding: C, conventional, H, hydroseeding, and T, trees.

TABLE 32. COST COMPARISON OF SEAL CONSTRUCTION

Work area no.	No. of seals	Type seal	Direct Cost, $	Cost per seal, $	Maximum, $	Minimum, $	Average, $
2	2	Dry	4,000	2,000	6,376	1,358	2,212
7	3	Dry	5,298	1,766			
8	1	Dry	6,376	6,376			
14	1	Dry	1,358	1,358			
27	12	Dry	23,706	1,975			
30	6	Dry	14,574	2,429			
101	1	Wet	5,031	5,031	5,032	3,128	4,076
24	1	Wet	4,068	4,068			
53	1	Wet	3,128	3,128			

SECTION 6

POSTRECLAMATION CONDITIONS AT THE PROJECT SITE

This section presents an evaluation of postreclamation conditions at the project site (Phase 3 of the project plan). As indicated earlier, the project was not completed as originally planned. Only the southern half of the Roaring Creek watershed was reclaimed; no reclamation was performed in the Grassy Run or the northernmost part of Roaring Creek watershed. Therefore, only those areas that were reclaimed and revegetated are considered in the evaluation, which includes the following points of concern:

1) Mine Seals
2) Chemical-physical characteristics of surface waters.
3) Surface runoff
4) Biological characteristics of surface waters
5) Long-term evaluation of Project Site.

Information pertaining to the first four categories was generated at various times between 1967 and 1971, the period from the end of reclamation to termination of the organized sampling and evaluation program.

The final category involves periodic and casual surveying of the reclaimed areas to determine long-term changes. These surveys have been carried out since termination of the organized sampling program (1971) and are still continuing as of the time of preparing this report.

MINE SEALS

Eleven "wet" seals were constructed in the large 1,200-hectare underground mine complex and one seal in a small isolated mine. Sealing of the large mine was not completed. All of the portals on the south half of the mine were sealed but several were left open on the north half. The subsidence over large parts of the mine was not corrected. Thus, it is not surprising that air samples collected from behind the "wet" seals in the large mine complex contained the same oxygen concentration as the air outside the mine. Although the air may not have entered the mine at the seals, it still may gain entrance to the mine through cracks and fractures in the overburden and outcrop, and through subsidence holes.

Monitoring of the quality and quantity of water discharging from nine mine openings has yielded the results reported in Table 33. The first eight openings listed in the table were into the large 1200-hectare mine. Even though the oxygen content behind the seal was never reduced, seven of the eight shown had reductions in acidity and sulfate concentrations. The data for the eighth opening, RT6-6, are complicated by extraneous factors. Although several reasons for this condition have been postulated, none has been verified.

The load data show little if any improvement, probably because of the increase in flow that has resulted since sealing. The increase in flow noted at several sites probably is due to more accurate measurements of flow after reclamation. Before reclamation, seepage at the base of highwalls and toes of spoils could not be measured. As a result of reclamation this water was forced out the main mine opening where it was measured.

Mine RT9-11 was a small isolated mine (only a few acres) in which all known openings were sealed. Unlike work on the large mine, it is believed that a good effort had been made to seal off all air entrances to the mine. As shown in Table 34, the oxygen content within the mine was reduced but not eliminated. For the first 2 years following sealing, the oxygen content fell below 11 percent. During the fourth quarter of 1969, the oxygen level rose to near 15 percent and has remained near that level since. Extensive investigation of the seal and the mined area has revealed no apparent holes into the mine. Thus no explanation of the increase in oxygen has been formulated.

The acidity, iron, and sulfate concentrations of the discharge from mine RT9-11 have shown some improvement (Table 34). Seasonal fluctuations have occurred as a result of the hydrologic conditions. Following sealing the total flow increased; thus the reduction in load is not nearly as great as that in concentration.

CHEMICAL-PHYSICAL CHARACTERISTICS OF SURFACE WATERS

This section evaluates changes in water quality as a result of reclamation and revegetation.

Methods

Sampling procedures before and after reclamation were similiar except that the frequency of sampling was altered.

TABLE 33. CHARACTERISTICS OF THE DISCHARGE FROM UNDERGROUND MINES BEFORE (1966) AND AFTER AIR SEALING[a]

Mine seal number	Acidity					Sulfate				
	1966	1968	1969	1970	1971	1966	1968	1969	1970	1971
						Concentration, mg/l				
RT 6-9	1,958	1,615	1,615	1,553	1,117	2,740	1,494	1,608	2,020	1,637
RT 6-23	1,942	1,455	1,312	1,257	1,060	2,114	1,567	1,560	1,738	1,268
RT 6-12	977	1,031	955	861	601	1,002	1,055	1,098	1,197	568
RT 6A-1	712	437	474	429	388	586	509	520	539	350
RT 6-3	217	195	181	178	164	427	412	358	353	257
RT 6-6[b]	264	2,193	2,422	2,381	2,222	408	2,022	2,380	3,200	2,619
RT 6-5	307	217	225	224	186	486	425	412	416	290
RT 5-2	837	664	a	a	a	1,147	799	a	a	a
RT 9-11[c]	591	331	348	279	275	1,035	685	674	671	498
						Load, tons/year[d]				
RT 6-9	59	266	221	184	214	79	248	220	218	320
RT 6-23	242	246	163	132	223	268	274	194	171	265
RT 6-12	65	129	135	68	64	68	136	152	94	66
RT 6A-1	17	11	6	8	14	10	13	6	14	13
RT 6-3	20	22	23	27	25	38	45	51	53	37
RT 6-6[b]	25	39	18	27	79	22	34	17	35	94
RT 6-5	240	171	172	97	167	399	350	315	213	243
RT 5-2	118	119	a	a	a	81	159	a	a	a
RT 9-11[c]	18	16	16	92	15	26	33	30	21	27
	Discharge, million cu. ft./year[e]									
RT 6-9	1	5.5	4.5	3.9	6.7					
RT 6-23	4.3	5.7	4.1	3.4	6.7					
RT 6-12	4.1	4.5	4.8	2.7	4.4					
RT 6A-1	0.6	0.8	0.4	0.6	1.4					
RT 6-3	3.4	3.9	4.7	5.1	5.1					
RT 6-6[b]	2.3	0.8	0.2	0.4	1.0					
RT 605	27.9	27.7	24.7	16.7	28.5					
RT 5-2	4.5	6.6	a	a	a					
RT 9-11[c]	0.9	1.5	1.4	1.0	1.7					

[a] Bulkhead seal constructed September 1969.

[b] The concentration was lower and volume higher during 1966 because surface runoff was measured along with the mine discharge.

[c] All mine seals, except RT 9-11 are into the 3,000 acre mine. RT 9-11 is into a small isolated mine.

[d] To convert short tons/year to metric tons per year multiply by 0.907.

[e] To convert cubic feet/year to cubic meters/year multiply by 0.028.

TABLE 34. EFFECTIVENESS OF MINE SEAL RT 9-11

		Oxygen within mine, percent	Acidity as $CaCO_3$, mg/l	pH[b]	Iron, mg/l	Sulfate, mg/l
Before sealing[a]						
Mean		21	591	2.8	93	1,035
Minimum			438	3.1[c]	48	710
After sealing						
Year - Quarter						
67	4	9.1	359	3.2	85	797
68	1	8.3	325	3.2	74	686
68	2	10.8	334	3.2	68	702
68	3	7.0	344	3.2	72	708
68	4	7.4	265	3.2	72	627
69	1		350	3.2	63	645
69	2		339	3.2	91	656
69	3	7.0	376	2.9	62	717
69	4	14.8	327	3.1	71	678
70	1	15.0	263	3.1	74	603
70	2	12.0	310	2.9	49	628
70	3		297	3.1	72	845
70	4	13.3	294	3.3	83	606
71	1	15.0	249	3.2	56	488
71	2	15.3	248	3.2	47	508
71	3	14.0	276	3.0	56	460
71	4		326	2.9	73	535

[a] March 1964 - August 1967.

[b] Median value.

[c] Maximum value.

Initially, streams and mine discharges were sampled weekly. After the first year following reclamation, however, samples were collected bi-weekly, and for the last year (1971), sampling was done monthly. Since 1971 surface water and mine discharge have been sampled twice, once in August 1974 and once in June 1975.

Chemical-Physical Data for Grassy Run Watershed (1968 to 1971)

Although no reclamation was performed in this watershed, it was believed that reclamation in parts of the Roaring Creek watershed that diverted water from the underground mine complex that normally flowed through the mine to Grassy Run would reduce the flow and possibly the pollution load in Grassy Run. The data summary for the monitoring station at the mouth of Grassy Run (G-1) is presented in Table 35. The data show that a reduction in acidity has occurred. If 1966 is used as a base year (because rainfall was similar to that of postreclamation years) then reductions of 705 tonnes (20 percent), 751 tonnes (21 percent), and 509 tonnes (15 percent) occurred during 1968, 1969, and 1970, respectively. In 1971 an increase in flow as a result of unusually high precipitation in September caused an increase of 122 tonnes of acidity over the base value. Reductions in iron and sulfate were also noted in 1968 and 1969; however they increased to levels above prereclamation in 1970 and 1971. The flow at the mouth of Grassy Run was greater after reclamation than before (19% to 46% for 1968-1970). This finding is difficult to explain since a decrease was expected. It may reflect the inherent problem of comparing annual rainfall and runoff data for different years. Quarterly data for this site are presented in the appendix. These data support the idea that the high loads in 1971 were a result of increased flow. Concentration values were lower during these periods as a result of dilution.

Chemical-Physical Data for Roaring Creek (1968 to 1971)

All reclamation work performed was in the Roaring Creek watershed. If the reclamation efforts were successful, then an increase in flow, because of the diversion of water from the underground mines, and a decrease in the concentration and load of pollutants would be expected.

If 1966 is considered the base year for before-reclamation conditions, then an increase in annual runoff of about 5 percent occurred in the 1968-1970 period (Table 35). This increase is probably not significant when the variables between years are considered. In 1971, a 166 percent increase in flow was recorded even though the annual rainfall was somewhat less in 1971 than in 1966. Approximately 60 percent of the annual runoff occurred in the third quarter of 1966, (Table A-56 in Appendix). This is an unusually higher amount for a period which normally

TABLE 35. SUMMARY OF ANNUAL DATA FOR STATION G-1, MOUTH OF GRASSY RUN, AND STATION R-1, MOUTH OF ROARING CREEK

Year	Rainfall, inches[a]	Flow, billion gallons[b]	Acidity, tons[c]	Iron, tons[c]	Sulfate, tons[c]
Station G-1					
Before reclamation					
1965	38.85	1.56	3,715	715	6,314
1966	43.05	1.39	3,891	691	4,909
After reclamation					
1968	42.73	1.66	3,108	617	4,326
1969	49.40	1.54	3,057	673	4,382
1970	44.71	1.98	3,325	779	6,437
1971	45.50	2.33	4,027	848	5,889
Station R-1					
Before reclamation					
1965	39.01	43.9	2,920	204	5,002
1966	46.62	50.1	3,928	280	5,842
After reclamation					
1968	43.82	51.9	3,728	279	5,046
1969	51.06	52.5	3,474	252	3,949
1970	47.60	52.2	3,383	244	3,495
1971	43.79	133.3	11,806	468	4,898

[a] To convert inches to millimeters multiply by 25.4.

[b] To convert gallons to cubic meters multiply by 0.0038.

[c] To convert tons to metric tons multiply by 0.907.

has low runoff. Most of this occurred in September when the precipitation exceeded six inches, more than 100 percent above normal. Thus, it is impossible from the data available to ascertain if a true increase in runoff has occurred as a result of reclamation.

A decrease in the acidity (5 to 14%), iron (0 to 13%) and sulfate load (14 to 40%) occurred in the 1968-1970 period. The load decreased each succeeding year (Table 35). This general trend continued until September 1971 when exceptionally high runoff resulted in a massive increase in pollution load even though the concentration did not change significantly (Table A-56 Appendix).

Chemical-Physical Data for Subwatersheds (1968 to 1971)

The use of the monitoring stations at the mouth of Roaring Creek and Grassy Run were felt to be inadequate to measure the effectiveness of individual control practices. For this reason, the project was divided into subwatersheds for evaluation. Location of the monitoring point for each subwatershed is shown in Figure 7 (see Section 4.0). Generally, the monitoring point was at the mouth of a small stream system. Each subwatershed is described below (Appendix A presents more detailed data on both the Roaring Creek and Grassy Run watersheds).

Mabie Subwatershed (RT8-F-1)--

The effect of reclamation on 20 hectares of disturbed land was measured at a sampling point located at the mouth of this 82-hectare subwatershed. A superb growth of grass and trees has been established in the reclaimed area. The underground mine discharge located in the area has not been sealed. During dry periods, the underground mine discharge makes up almost the entire flow of the creek. Any improvement in water quality can be attributed to reclamation of the surface mines.

As shown in Table 36, a continued improvement in water quality has occurred. The marked improvement in 1968, followed by an increase in concentration during 1969, may be partially from the reduced effect of lime that was applied in 1968 during revegetation. Concentration data obtained in 1970 and 1971 show a continuing long-term improvement in water quality. The pollutional load data show a similar trend. The load was greater in 1971 than 1970 because much higher runoff occurred during periods of heavy rainfall in 1971. The approximate decreases in acidity and sulfate loads due to reclamation have been 82 and 78 percent, respectively.

North Branch Flatbush Fork Subwatershed (RT9-2)--

This 280-hectare watershed contains 65 hectares of surface mines (23 percent of land area), all of which were reclaimed. One underground discharge is located in the watershed; however,

TABLE 36. SUMMARY DATA, MABIE SUBWATERSHED (RT8F-1) BEFORE AND AFTER RECLAMATION

	Acidity	Iron	Sulfate
Mean concentration, mg/l			
Before reclamation			
1965 - 1966	199	19	290
After reclamation			
1968	74	10	159
1969	123	16	211
1970	95	9	193
1971	76	4	105
Load, tons/year[a]			
Before reclamation			
1965 - 1966	39[b]	4.7[b]	52.1[b]
After reclamation			
1968	12.5	1.6	26.0
1969	23.7	4.5	64.5
1970	5.6	0.5	11.5
1971	9.0	0.5	12.4

[a] To convert short tons/year to metric tons/year multiply by 0.907.

[b] Incomplete data.

its acid load contribution is minor (less than 1 percent). Except for a few isolated areas an adequate-to-excellent cover of grass and legumes has been established. Table 37 summarizes the data collected at the mouth of the watershed.

Concentrations of acidity and sulfate decreased during the 1968-1971 postreclamation period; the acidity concentration by 59 percent and the sulfate by 63 percent. No reduction in the relatively low iron concentration occurred. Pollutional loads also show a decreasing trend except for the increase in 1971 caused by heavy precipitation and runoff.

Lower Kittle Run Subwatershed (RT6-20)--

This 85-hectare watershed contains 18 hectares of surface mines (21 percent of land area) and two underground mine discharges. As shown in Table 38, the data are indeterminate with respect to water quality and waste load. The sources of mine drainage in this watershed were analyzed. Before reclamation, approximately 54 percent of the pollution load was from the underground mines. After reclamation (1968-1971) the contribution of underground mines increased to between 75 and 90 percent of the total load. Since the total load has remained about the same, the contribution from the surface mines has decreased since reclamation. Although the underground mines have been air sealed, the sealing has not been effective in reducing the pollution load (see Table 38); in fact, the load has increased in some cases. Although this increase is difficult to explain completely, it may be due to changes in drainage caused by roof falls within the mine and by reclamation.

Upper Kittle Run Subwatershed (RT6-21)--

This watershed is located at the mouth of Upper Kittle Run, one of the most devastated areas in the project. The streambed had been completely destroyed during mining when overburden was deposited in the creek. Surface runoff and underground mine drainage in the headwaters were partly directed into underground mines. Thus the sample site at the north of the creek was not indicative of the total pollution contribution. During reclamation 57 hectares of surface mines were regraded and planted, several refuse piles and garbage dumps were buried, six clay seals were installed in deep mine openings, and two wet seals were constructed. The streambed also was reestablished, thus directing all of the runoff past the control point. Except for isolated areas, the cover of grasses and legumes is adequate to very good.

Data pertaining to this area are presented in Table 39. The prereclamation data do not show the total pollution load of the watershed, since part of the water was directed into the underground mine upstream from the sampling point. Thus the load values would have been greater than those reported. The acidity concentration data show a long-term decreasing trend; the iron

TABLE 37. SUMMARY DATA, NORTH BRANCH FLATBUSH FORK WATERSHED (RT 9-2) BEFORE AND AFTER RECLAMATION

	Acidity	Iron	Sulfate
Mean concentration, mg/l			
Before reclamation			
1964 - 1966	178	5	313
After reclamation			
1968	68	4	225
1969	96	5	208
1970	93	5	202
1971	74	4	117
Load, tons/year[a]			
Before reclamation			
1965	187	6.4	338
1966	243	7.5	436
After reclamation			
1968	153	7.2	450
1969	131	8.0	268
1970	107	5.7	232
1971	214	11.6	338

[a] To convert short tons/year to metric tons/year multiply by 0.907.

TABLE 38. SUMMARY DATA, LOWER KITTLE RUN SUBWATERSHED (RT 6-20) BEFORE AND AFTER RECLAMATION

	Acidity	Iron	Sulfate
Mean concentration, mg/l			
Before reclamation			
1964 - 1966	486	91 (40)	616
After reclamation			
1968	613	148 (43)	686
1969	783	232 (10)	881
1970	687	254	1,017
1971	532	150	587
Load, tons/year[a]			
Before reclamation			
1965	113	21	152
1966	149	33	168
After reclamation			
1968	183	48	211
1969	183	55	216
1970	192	71	335
1971	191	48	182

[a] To convert short tons/year to metric tons/year multiply by 0.907.

TABLE 39. SUMMARY DATA, UPPER KITTLE RUN SUBWATERSHED (RT 6-21) BEFORE AND AFTER RECLAMATION

	Acidity	Iron	Sulfate
Mean concentration, mg/l			
Before reclamation[a]			
1965 - 1966	1,555	328	1,768
After reclamation			
1968	1,127	309	1,179
1969	1,060	330	1,243
1970	982	307	1,519
1971	738	205	898
Load, tons/year[b]			
Before reclamation[a]			
1965	684	148	829
1966	868	175	944
After reclamation			
1968	683	192	737
1969	575	183	652
1970	434	135	678
1971	578	146	691

[a] The before and after reclamation data are not directly comparable, because some of the pollution load developed in the watershed prior to reclamation was diverted to the underground mine and thus did not pass the control point.

[b] To convert short tons/year to metric tons/year multiply by 0.907.

and sulfate concentrations are lower than before but the decrease is slight. The load data are irregular, reflecting the influence of year-to-year variations in precipitation (amount, intensity, duration, etc.) and the effects of groundwater and runoff. Even with these variations, however, it can be concluded that the load is less.

Table 40 presents data from an analysis of sources of mine drainage in this watershed after reclamation. Interestingly, even though the area contributing to runoff from the watershed was greater after reclamation, the acid and sulfate load decreased. The pollution load from underground mines remained the same or increased. These data indicate that reclamation of the surface mines and burial of the refuse piles resulted in a reduction of pollution. The variation in contribution of the surface mines may be due to yearly variations. Variations during 1969 and 1970 may be due to the decreasing benefit of lime applied to the soil during revegetation.

SURFACE RUNOFF

One of the major control techniques demonstrated in the Elkins project was the diversion of water from the underground mines. A method of evaluating the effectiveness of this method would be the monitoring of the runoff from the area and the underground mine discharge. When these data were evaluated, it became apparent that discharge data collected once a week or a month were inadequate. Thus, the only information available that related to increased runoff were observations of increased peak flows and flooding of areas that had not flooded before reclamation.

BIOLOGICAL CHARACTERISTICS OF SURFACE WATERS

As part of the third phase of the demonstration project, this section describes changes in the aquatic biota brought about by partial mine reclamation and resultant changes in water quality. The same reclaimed subwatersheds delineated in this section were examined. For comparative purposes, additional polluted and nonpolluted mainstem and tributary reaches that had been sampled previously were reexamined.

Methods

Biological investigations of Roaring Creek and selected tributaries were conducted from March 17 to 19, 1970. Benthos (bottom-dwelling invertebrates) were collected from shallow riffle areas by use of a Surber square-foot sampler or a Petersen dredge. Qualitative samples were collected by agitating stream-bottom debris on a U.S. Standard No. 30 sieve to roughly separate organisms from debris and by picking and scraping organisms from submerged rocks and logs. Organisms and sieve

TABLE 40. POLLUTION LOADS AND THEIR SOURCES, UPPER KITTLE RUN SUBWATERSHED (RT 6-21)[a]

	1966,	1968		1969		1970		1971	
	tons	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Acidity									
Total	868	683	100	575	100	434	100	578	100
Underground	301	512	74	384	66	316	72	436	75
Surface mines	c	171[b]	26	191[b]	34	118[b]	28	142[b]	25
Iron									
Total	175	192	100	183	100	135	100	146	100
Underground	68	136	70	113	61	85	63	127	87
Surface mines	c	56[b]	30	70[b]	39	50	37[b]	19	13
Sulfate									
Total	944	737	100	652	100	678	100	691	100
Underground	347	522	70	414	63	389	57	585	84
Surface mines	c	215[b]	30	238[b]	27	289[b]	43	106[b]	16

[a] To convert short tons/year to metric tons/year multiply by 0.907.

[b] Assumed to be difference between total and underground.

[c] Cannot be determined because not all water in watershed drained past control point during pre-reclamation.

residue were preserved in 10 percent formalin solution and returned to an EPA laboratory at Cincinnati for sorting and enumeration. Benthos data are expressed as numbers of organisms per square foot of stream bottom. Qualitative samples were arbitrarily assigned values of 1 per square foot for counting.

No data on periphyton or fish were collected.

Biological Data For Subwatersheds And Related Tributaries (1970)

The stations sampled for biological data are not identical to those sampled for chemical-physical data. Although the sampling stations are not identical, they do represent common drainage areas within the respective subwatersheds.

Headwaters--

Before the partial completion of reclamation projects in 1968, several Roaring Creek headwater areas were free from serious damage caused by mine drainage. Stations R-8, R-9, RT10-1, and RT10-2 (see Figure 13) were inhabited by diverse assemblages (>25 kinds) of benthic invertebrates, including many forms considered sensitive to mine-drainage toxicity (10). In 1970, these stream reaches continued to support diverse biotic communities, including sensitive May flies, stone flies, caddis flies, black flies, and crayfish (Table 41).

Mainstem station R-7 was severely polluted by waters emanating from a nearby surface mine during the early part of the demonstration project, supporting a limited variety of tolerant organisms. Prior to the 1970 survey, the mine ceased operations and water quality improved. In March 1970, the benthos population was still sparse because the stream bed was blanketed with iron precipitates. Nevertheless, sensitive May flies, stone flies, and caddis flies now inhabit the area (Table 42).

Flatbush Fork Subwatershed (RT-9)--

The South Branch of Flatbush Fork watershed has had limited mining (Figure 13). These waters, monitored at Station RT9-3, were of good quality, supporting diverse benthic communities (Table 41). The waters monitored at Station RT9-2 flow from a small subwatershed that was extensively mined. The surface mine in this area was subjected to reclamation, but, the subsurface mine was not altered. In June 1970, aquatic invertebrates were completely absent from this stream reach (Table 41).

Reclamation activities in subwatershed RT9-2 effected some improvements in water quality; these improvements may have resulted from addition of lime to the soil during surface mine reclamation. Mixture of these waters with those from RT9-3 produced a substantial improvement in water quality downstream at Station RT9-23. Prior to reclamation, this stream reach was inhabited by low densities of tolerant organisms only. In 1970,

TABLE 41. BENTHIC ORGANISMS, ROARING CREEK, MARCH 1970

Stations:	R-1	R-2	R-2A	R-3	R-4	R-5	R-6	R-7	R-8	R-9	RT5-1	RT6-1	RT8-F1	RT9-2	RT9-3	RT9-23	RT10-1	RT10-2
STONE FLIES																		
Brachyptera				Q[b]	1	2		Q	1	Q			Q		4	Q	4	11
Isoperla									Q	Q					Q		Q	3
Nemoura										Q								1
Peltoperla																1	Q	Q
MAY FLIES																		
Ameletus															Q		Q	3
Blasturus							Q	Q					Q					
Ephemerella									1	2					Q	Q	Q	Q
Hexagenia										Q								
Stenonema									1									3
CADDIS FLIES																		
Cheumatopsyche				2					2	Q					1	Q		12
Hydropsyche																	Q	2
Polycentropus			1		Q				1							1	Q	3
Psychomyia															5	Q	Q	4
Ptilostomis											Q	Q				Q		
Pycnopsyche			Q					Q	Q	Q							Q	Q
BLACK FLIES																		
Prosimulium									Q						1		Q	4
CRANE FLIES																		
Helius						110												1
Hexatoma				2			Q								1			Q
Pedicia				4														
Tipula	Q			Q	Q	Q	2	Q	Q	Q					Q	Q		1
BITING MIDGES																		
Probezzia				1		2							1					1
MIDGES																		
Chironomus			Q								1	2	2					
Metriocnemus		Q	1	3	Q	11	3	Q			Q		29		Q			2
Microtendipes																		19
Pentaneura				Q					1		Q						Q	1
Spaniotoma				7	1	2												
Tanytarsus										1					3			10

(continued)

TABLE 41 (continued).

Stations:	R-1	R-2	R-2A	R-3	R-4	R-5	R-6	R-7	R-8	R-9	RT5-1	RT6-1	RT8-F1	RT9-2	RT9-3	RT9-23	RT10-1	RT10-2
DANCE FLIES													1					
HORSE FLIES																		
Tabanus			Q										Q		Q			
HELLGRAMMITES																		
Chauloides				Q											Q			5
Sialis	1	Q	1	2		2				Q	1	1	2				1	
BEETLES																		
Narpus	Q						2											
SLUDGE WORMS				9		18	1		3	Q					1			7
LEECHES										Q								
FLATWORMS																		12
SPHAERIID CLAMS																		1
CRAYFISH										Q						1	Q	Q
SOW BUGS																		
Asellus															Q			2
TOTAL																		
No/ft^2	3	2	6	34	5	148	10	5	14	14	5	4	38	0	24	9	16	113
No. kinds	3	2	6	12	5	8	6	5	11	13	5	3	8	0	15	9	13	27

[a] To convert numbers/square feet to numbers/square meter multiply by 10.76.

[b] Q = collected in qualitative sample only. Arbitrarily assigned a value of one/square foot for counting purposes

TABLE 42. BENTHIC ORGANISMS COLLECTED BEFORE AND AFTER RECLAMATION OF MINED AREAS

Mainstem station	Black flies		May flies		Caddis flies[a]		Stone flies		Crayfish	
R-1										
R-2										
R-2A						A				
R-3					B	A	B	A		
R-4						A	B	A		
R-5								A		
R-6				A						
R-7				A		A		A		
R-8	B[b]	A[c]	B	A	B	A	B	A	B	
R-9	B		B	A	B	A	B	A	B	A
Tributary station										
RT5-1										
RT6-1										
RT8F-1				A				A		
RT9-2										
RT9-3	B	A	B	A	B	A	B	A	B	
RT9-23				A		A		A		A
RT10-1	B	A	B	A	B	A	B	A	B	A
RT10-2	B	A	B	A	B	A	B	A	B	A

[a] Excluding ptilostomis

[b] B = collected before reclamation

[c] A = collected after reclamation

sensitive May flies, caddis flies, stone flies, and crayfish inhabited the stream (Table 42). Because the stream bed was blanketed with iron precipitates, the density of organisms remained low (Table 41), and sessile organisms such as sensitive black flies had not become established. However, the stream bottom should consolidate eventually, allowing for the establishment of a well-balanced assemblage of benthic invertebrates.

Mabie Subwatershed (RT8-F-1)--

This small watershed contained both surface and subsurface mines. Although the surface mines were reclaimed, the underground mine, which contributed most of the pollutional load, was not sealed. Prior to 1970, water quality at RT8-F-1 was poor. Water quality was temporarily improved by reclamation procedures, perhaps by application of lime to the surface mine. This improvement was reflected by the presence of sensitive May flies and stone flies in the water in 1970. (Whether this level of water quality and resultant sensitive benthic populations will continue is not known).

Kittle Run Subwatershed (RT-6)--

This watershed was mined extensively (both surface and deep mines) and contributed great amounts of pollutants to Roaring Creek. Demonstration efforts were directed at these mines, including surface reclamation and installation of several types of underground mine seals. As a result of these efforts the quality of surface runoff was improved but discharges from the underground mines continued to be polluted severely. Prior to reclamation efforts, the stream biota (monitored near the mouth at RT6-1) were restricted to organisms tolerant of mine-drainage pollution. In 1970, the biota had not changed. Only benthic organisms tolerant of severe pollution inhabited the stream, in very low densities (Table 41).

White's Run Subwatershed (RT-5)--

This severely polluted watershed contained one underground mine, which was sealed. Although water quality improved, the stream bottom was covered with iron precipitates. Damage to the stream biota continued in 1970, the benthos consisting of tolerant *Ptilostomis*, midges, and *Sialis* in very low densities.

Mainstem Roaring Creek--

As previously stated, the benthos of Roaring Creek indicate good water quality from the headwaters to Station R-7. At the next sampling point downstream (R-6), the creek carried pollutants from Flatbush Fork and the Mabie area and possibly from other sources. From Station R-6 downstream to R-3, the toxicity of mine drainage damaged the biota of the stream bottom; the diversity of benthic invertebrates was restricted to a few kinds, mostly forms tolerant of acidic mine drainage (Table 41). Significant differences were detected, however, in the invertebrate communities inhabiting Roaring Creek from R-6 to R-3 before and after reclamation. Sensitive May flies, stone flies, and caddis flies were collected for the first time in 1970 (Table 42). Thus, the quality of Roaring Creek waters improved sufficiently after reclamation to allow the establishment of more diverse benthic biota.

Downstream from Station R-3, vast quantities of pollutants are discharged to Roaring Creek from stations RT6 and RT5. From R-2A to the mouth, the invertebrate communities of Roaring Creek were severely restricted by mine-drainage toxicity. Pollution tolerant larvae of midges and alderflies (Sialis) were prevalent in the benthos, whereas sensitive organisms such as May flies and stone flies did not inhabit the stream reach. Comparisons of benthic communities inhabiting this highly polluted reach of Roaring Creek before and after reclamation revealed no significant differences (Table 42); the benthos continued to show severe damage after partial completion of control measures.

LONG-TERM EVALUATION

There have been no extensive or regularly scheduled investigations of the project site since the termination of all sampling programs in the early 1970's. Since that time, however, the study area has been periodically inspected for assessment of any long-term changes. What follows is a summary of the investigations carried out at the project site in recent years.

Chemical-Physical Data for Subwatersheds (1971 to 1975)

As indicated previously only two sets of samples have been collected since 1971 (16).

It is difficult to compare the results of these surveys with one another or with previously collected information because these data represent only one sampling period each, and because one data set (1974) was collected during low water flow whereas the other (1975) was collected during high flow.

For these reasons any attempts to draw strong inferences from the 1974 and/or 1975 data may generate spurious conclusions. The only general conclusion that can be drawn is that these data indicate no extreme changes in water quality since the early 1970's.

Present Biology Of Surface Waters

A biological sampling was being conducted during the writing of this report (Fall 1976). It was not available for discussion in this report. Reports from local fisherman and personnel from the West Virginia Division of Natural Resources indicate that fish life has returned substantially to the Tygart

Valley River both above and below the mouths of Roaring Creek and Grassy Run. Additionally, stocking has been sucessful in the Tygart Valley Reservoir (downstream from the project site), and fishing has progressively increased. These considerations, as well as the improved water quality of the surface waters within the project site since reclamation suggest that the biology of Roaring Creek and Grassy Run has improved substantially since prereclamation time.

Assessment of Work Areas

Since the completion of reclamation the project site has been surveyed numerous times for the purpose of assessing (1) vegetation growth, (2) condition of seals, and (3) erosion and subsidence problems.

The data generated from a specific survey on November 28, 1973, are summarized in Table 43.

These data show that all areas investigated have stabilized and support a good growth of grasses and trees (where planted). There are no apparent major problems of erosion, subsidence, or acid mine water seepage. Results of the 1973 and a 1976 survey are discussed briefly below.

Trees--

All species of trees planted show some degree of growth, with survival rates ranging from 40 to 75 percent. The European black alder has exhibited the highest survival rate and best growth pattern (average height 2.5 to 5 meters). In 1973, some of the black alder began to die. It was postulated that the trees were being attacked by insects and/or the disease cytospera. The trees were still showing signs of this attack in 1976. The cause of the die back has not been verified (Figure 34). Other deciduous trees, such as Japanese larch (Figure 35) tulip poplar, and white oak have also done nicely, but the survival and growth rates were somewhat less than those of the black alder. Density of cottonwood trees is low. The various species of pines have also taken hold and are showing continual growth. Estimated survival rates ranged from 35 to 50 percent, and average height ranged from 1 to 1.5 meters. A few pines in Work Areas 28 and 30 appear to be dying.

Grasses and Legumes--

The grass growth at all work areas was rated excellent on the basis of percent of ground covered (85 to 100%) and thickness of the grass mat (heavy in all areas except Work Area 3). The grasses and legumes exhibiting best growth include tall fescue, oat grass, orchard grass, and Kentucky bluegrass (Figure 36). Legumes showing best growth have been *Sericea lespedeza*, birdsfoot trefoil and alsike clover. The dominant cover was *Sericea lespedeza*, (Figure 37) trefoil, and orchard grass.

TABLE 43. 1973 EVALUATION OF CONDITIONS AT SELECTED WORK AREAS (FIVE YEARS FOLLOWING PLANTING)

Work area No.	Work area size, acres[a]	Type of backfill	General conditions of grass and trees[c]	Percent of grass cover[c]	No. of bare spots, >1/2 acres	Average height of trees, feet[b]	Conditions of seals	Major erosion problems	New subsidence	Land use
2	40.3	Pasture	trees: 60% survival grasses: heavy cover	95	2	larch: 7 alder: 8 cottonwood: -	good	Drainway has eroded, 1 to 2 meter deep gulley	none	Wildlife
3	9.5	Pasture	trees: minimal growth grasses: light cover	85	2	larch: 4 to 5 alder: 6	no seals	none	none	Wildlife
4	4.7	Pasture	trees: non-planted grasses: heavy cover	90	1	non-planted	no seals	none	none	Wildlife
5	4.3	Pasture	trees: non-planted grasses: heavy cover	85	2	non-planted	no seals	none	none	Wildlife
6	12.0	Pasture	trees: non-planted grasses: heavy cover	90	1	non-planted	no seals	none	none	Wildlife
7	17.0	Contour	trees: non-planted grasses: heavy cover	90	1	non-planted	good	none	none	Wildlife
8	7.9	Pasture	trees: non-planted grasses: heavy cover	90	1	non-planted	no seals	Two drainways have eroded, 1 to 3 meters deep	none	Wildlife
9	11.7	Pasture	trees: non-planted grasses: heavy cover	100	none	non-planted	no seals	none	none	Wildlife
27	60.0	Contour	trees: 35-60% survival grasses: heavy cover	95	2	alder: 12 to 16 pines: 3 to 5	acid mine water seepage from dry seals	Slight erosion in area of seeping seals	1	Wildlife
28-30	40.7	Contour	trees: 40-75% survival grasses: heavy cover	100	none	alder: 14 pines: 3	good acid mine water flow from wet seals	Slight erosion	1 (1 by 4 meters)	Wildlife 60% wildlife & 40% pasture
44	26.7	Contour	trees: good growth grasses: heavy cover	99	none	alder: 12 popular, cottonwood, and white oak: minimal				

---

[a] To convert acres to hectares, multiply by 0.405.

[b] To convert feet to meters, multiply by 0.305.

[c] Grass means grass and legumes.

Figure 34. European black alder and Sericea lespedeza - Area 10.

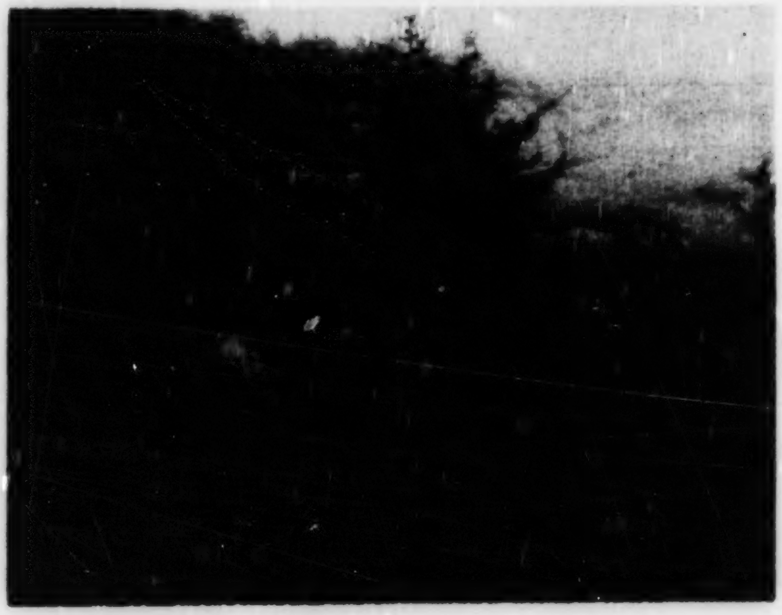

Figure 35. Japanese larch - Area 22.

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best available copy.

Figure 36. Grass growth - Area 6.

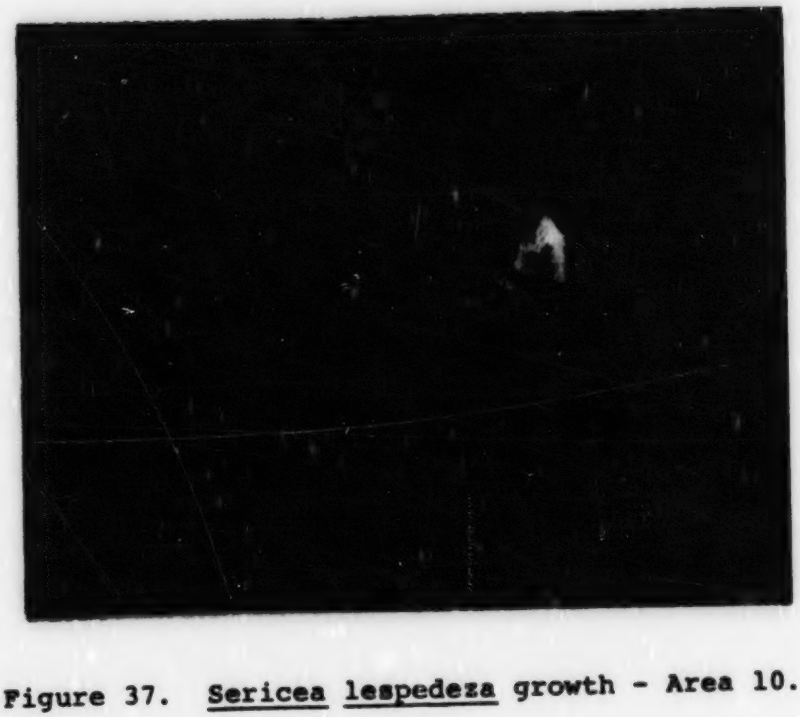

Figure 37. Sericea lespedeza growth - Area 10.

Weeping love grass, Canadian barley, Belgium rye grass, and sweet clover were nonexistent in most areas, and were sparse in the areas where they were observed.

During the first two years following planting, weeping love grass dominated on spoils that had lower pH's. Fescue was the major grass in areas with higher pH spoils. Canadian barley grew well the first year. As the weeping love grass, a superior nurse crop, died and the available nitrogen decreased, the legumes became dominant in most areas and maintained that position in 1976. Except for a few experimental plots, additional lime and fertilizer has not been applied. After eight years, it does not appear as if soil admendments are necessary to maintain good cover.

One or two bare spots larger than 1/4 hectare were noted in all work areas except 1, 28, 29, 30, and 44. One large bare spot in Work Area 27 has resulted from seepage of acid mine water from a number of dry seals (Figure 38). Access roads in Work Areas 5 and 6 have also caused several bare spots.

Erosion--

No major erosion problems were recorded during the 1973 or 1976 survey. The worst problems were several drainways in Work Areas 2, 8, 28, and 30 which contained gulleys 1 to 3 meters deep (Figure 39). The gullies were usually formed when grass waterways carrying runoff discharged over the outslopes of backfilled areas. This problem could have been prevented had the waterway been lined with rock. Erosion appeared to have stabilized by 1973 because gullies had not increased in size by 1976. Slight erosion attributed to the acid water seepage was also noticed in Area 27 (Figure 38).

Seal Condition--

All seals inspected were in good condition except for the dry clay seals in Work Area 27. Acid mine water had broken through the seals killing all of the vegetation.

Land Use--

Land use of all work areas except 44 is for wildlife. Deer have been sighted in most reclaimed areas. Forty percent of Area 44 was being used for pasture; 60 percent was in wildlife.

The study site was surveyed in March and July, 1976, for purposes of evaluating and bringing up to date the long-term changes which have occurred at the project site. Study areas in both Grassy Run and Roaring Creek watersheds were visited and assessed. The survey, however, did not involve physical sampling or taking of measurements.

This survey indicated that there have been no significant changes in conditions since the 1973 evaluation. However, the

Figure 38. Grass killed by acid water seeping from leaking clay seals - Area 27.

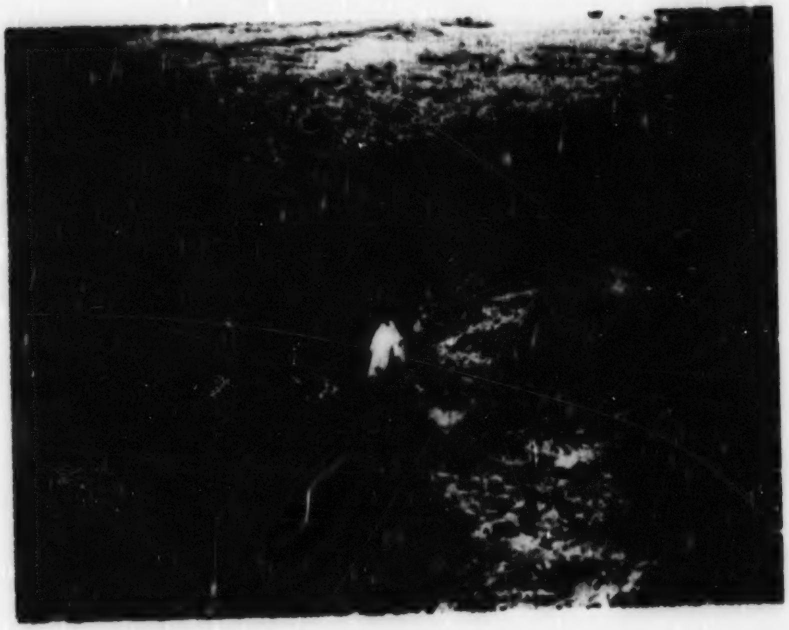

Figure 39. Gully formed where water from a grassed waterway was discharged over the outslope of a fill area - Area 2.

continual success of vegetation growth was witnessed. Grasses have continued to develop heavy mats in those areas where revegetation was performed. Several bare spots still exist as a result of acid mine drainage. The most visible bare spots are in Work Areas 10, 23, 24, and 27.

The various species of trees planted are also showing good progress. European black alder and the various species of pines planted are doing better than the larch, poplars and oaks (particularly in Work Areas 27 and 31). There has been, however, an increase in the number of deaths among the alders in recent years. Trees in Work Areas 23 and 24, which exhibited limited growth during early postreclamation days as a result of acid mine drainage, are now showing signs of substantial improvement. In those areas where reclamation was not performed (northern part of Roaring Creek and all of Grassy Run watersheds) pioneer vegetation is developing. Maple and locust, as well as a few oaks, appear to be the dominant forms growing.

The various types of mine seals installed remain in good condition and there have been no major changes since the 1973 survey. Acid mine drainage continues to flow from the clay seals in Work Area 27 resulting in the bare spots previously mentioned. Limited erosion also exists in this area as a result of the drainage. No new erosion or subsidence problems were detected during the 1976 survey.

Wildlife is still the major form of land use in the project site. A limited amount of grazing exists in Work Areas 18, 19, 36, and 44. Less than 12 hectares of the entire 287 hectares revegetated are in grazing.

SECTION 7

SPECIAL STUDIES

Several small scale feasibility studies dealing with a variety of technical problems were made during the course of the demonstration project. Brief summaries of the purpose of each of these studies are presented in this section. For detailed information on the findings of these studies refer to the reports referenced.

REVEGETATION FEASIBILITY STUDIES

Prior to revegetation, the USFS Northeastern Forest Experiment Station at Berea, Kentucky, in cooperation with the Tygart Valley Soil Conservation District and the Soil Conservation Service, made test plantings on the reclamation area to determine the feasibility of establishing vegetation on the spoil areas (17).

Initial testing began using 13 summer annual grasses and legumes. Annuals would be useful in establishing quick cover to combat erosion and would also provide protection for tree seedlings during the first growing season. Very little growth was noted in the highly toxic Kittanning seam spoil areas as compared to those test sites located in less toxic Sewell coal spoils. Even though the rainfall was well below normal during the test period, acceptable growth was noted in several species after fertilizer was added to the spoil. Pearl millet, velvet beans, cane sorghum, German millet, buckwheat, and Sudan grass exhibited acceptable growth in the fertilized spoil.

Lack of success on Kittanning spoil was attributed to (1) aluminum toxicity and (2) excess manganese. Stubby roots, lack of lateral roots, and browning of root tissue are characteristic of aluminum toxicity and were observed in Kittanning plants. Chlorosis (white leaves with green veins) was also observed and indicates iron deficiency. This iron deficiency was believed caused by excess manganese which inhibits iron uptake or utilization by plants.

The initial study concluded that the use of grasses and legumes would not be feasible on the Kittanning spoil due to the low pH and toxicity. It went on to conclude liming would solve the problem but USFS felt the amounts required would not be feasible. They recommended exclusive use of acid-tolerant trees and shrubs for spoils with pH's below 4.5.

USFS found the less toxic Sewell spoils more amenable to revegetation and recommended use of any of the following in conjunction with fertilizing:

Shrubs	Grasses	Legumes
Autumn olive	Tall oat grass	Birdsfoot trefoil
Bristly locust	K-31 fescue	*Serecia lespedeza*
Bicolor lespedeza	Rye grass	
Black locust	Orchard grass	
	Timothy	
	Weeping love grass	
	Switchgrass	

Later tests by the same people on Sewell spoil confirmed that the spoil contained virtually no nitrogen or phosphorus, thus it needed fertilizer. Also, the rate of water infiltration into the spoil was very poor, necessitating scarification to retain sufficient moisture for plant growth. This study concluded that domestic rye grass and weeping love grass produced the most successful cover. Sweet clover and alfalfa were moderately successful.

Studies on tree and shrub suitability were also made on the Sewell spoil. Evaluation of survival after one year indicated the following as having adapted successfully to the harsh environment:

Conifers	Hardwoods
Pitch pine	European alder (most successful)
White pine	Bristly locust
Douglas fir	Black locust
Norway spruce	Sweet birch
Eastern hemlock	Red maple
Canadian hemlock	

INFRARED AERIAL PHOTOGRAPHY STUDY

Itek Optical Systems Division suggested the possibility of using infrared aerial photography to indicate toxic soil. Previous work had shown non-toxic exposed soil to appear in gray and brown hues on infrared positive prints, however, acidic soil tended to appear cyan (blue-green). Itek proposed that these cyan hues might be useful in reclamation and revegetation by pinpointing highly toxic areas (18).

A feasibility project was extended to Itek to attempt to correlate infrared colors and intensities with soil toxicity. The strip mined areas at Norton and Coalton were used for test sites and two photographic overflights were made; the first during a wet period, the second during a dry period.

Suspicious areas were marked on the resulting prints and soil samples were taken at the indicated sites. Unfortunately, the time lag between the time of the flight, film processing, evaluation, final selection of the sampling site, and the time of soil sampling allowed considerable possibility for change in soil conditions. Duplicate soil samples were taken at each indicated site and were separately analyzed by the FWPCA Laboratory (EPA) and by USGS Denver laboratory with conflicting results. The lack of analytical correlation invalidated in-depth study of possible correlations between individual soil chemical constituents and infrared image tone.

Attempts at visual color comparisons were largely unsuccessful as were photometric analyses by a Macbeth densitometer. However, a statistical interpretation of the photometric data did indicate the possibility of a relationship existing between integral density and soil iron concentration.

In summary, the feasibility of using infrared aerial photography to indicate relative soil toxicity was not demonstrated. It is possible that further refinements of the process and a more detailed study could establish more promising results.

SUBSIDENCE AREA GROUTING STUDY

A contract was awarded to Dowell, Inc., to study the feasibility of pressure grouting subsidence areas to prevent entrance of surface water into the drift mines (19). Five test sites were selected on the project. Three sites were pressure-grouted using a mix of approximately 90 percent cement and ten percent bentonite. The intent was to seal fractures in the overburden via the lateral spread of grout. Unfortunately, water permeability tests before and after grouting indicated free flow into the mine from the subsidence test areas. Increasing the bentonite content to 32 percent did not appreciably aid in sealing and several grouting patterns were used.

The final technique tested was to grout to a very shallow depth in an attempt to form an impervious cap of grout covering the fractured subsidence area. Pressures to 400 psi succeeded only in forcing the grout to the surface but very little lateral movement was observed.

In their report on the study, the Bureau of Mines concluded ".....that grouting in rock would involve tremendous quantities of cement and bentonite with no assurance of success, and that attempting to establish an impervious cap over the fractured rock within the surface subsidence area is impractical due to the need of considerable pumping grout pressure to spread the grout laterally which will, in most cases, find an easier path to the surface or into the mine."

VACUUM FILTRATION STUDY

Johns-Manville Research and Engineering Center conducted a small scale feasibility study at Norton on neutralized acid mine drainage and sludge dewatering by vacuum filtration (20).

In the test plant, water was pumped into a "Mixmeter"* type lime neutralization unit where the pH was increased above pH 6.5. A portion of the neutralized slurry (approximately 0.63 l/sec) was pumped to a 7.0 m^3 upflow settling tank for precipitation. Settled sludge from the tank could be continually withdrawn and sent to the vacuum filtration unit.

A precoat vacuum filter unit was used and many types of filter aids were evaluated during the study. Sludge solids content of less than one percent from the settling tank were increased by precoat vacuum filtration to better than 20 percent in all cases.

Turbidity of the filtrate was generally less than 1.0 JTU and residual iron was below 0.3 mg/l. Air drying the filter cake as in land fill further increased the solids content from 20 to 75 percent. Johns-Manville reported that the cost of such treatment, including 1.3 cents/m^3 for lime, was approximately 2.8 cents/m^3 of AMD treated. This cost is for lime and filter aid alone, not for total process cost.

'CELITE' precoated filteraid, a drum speed of 60 revolutions per second, mergence of 30 seconds, and cake removal (cut) of 0.008 cm per revolution, filtered 1.00 $m^3/m^2/s$ of AMD sludge. This was the most successful combination studied by Johns-Manville at the Norton site.

HALLIBURTON MINE SEALS STUDY

The Halliburton Company developed mine sealing techniques using quick-setting, self-supporting sodium silicate-cement slurries to construct barrier walls (21). In this technique, a rear barrier wall is installed in a mine opening and limestone aggregate is then placed against the rear barrier wall and in the area in front of the bulkhead for a length of 3-5 meters.

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* Mention of commercial products does not imply endorsement by Environmental Protection Agency.

Grout pipes are strategically placed in the limestone aggregate and the front bulkhead is built against the sloping aggregate. The grout pipes pass through the front barrier wall. Finally, the aggregate section of the seal is grouted via the pipes to fill voids in the stone and produce an impervious seal.

It was desirable to test this technique on a high flow mine and site RT5-2 on the project area was chosen for this test.

Construction of the seal was completed in July 1969. A pitot tube was installed to monitor water level buildup behind the seal. A rapid increase in level occurred initially but tapered off in a few days. An increase in flow was observed from a wet seep located approximately 9 meters to the right of site RT5-2's new seal. Emergence of the seep corresponded with the reduction in water level buildup behind the RT5-2 seal and subsequent exploration exposed a second mine opening. As the water level behind RT5-2 increased, the water had been diverted through a cross-cut and was now emerging from the second opening.

Thus it was necessary to seal the second portal before it would be possible to increase the water level behind seal number one. Under Contract No. 14-12-453, Halliburton had done preliminary feasibility studies on 'permeable plug' seals. A permeable plug seal consists of filling the mine opening with graded limestone. The upper portion of limestone is grouted to assure a tight bond between the top of the mine and the limestone to compensate for any settling which might occur. In this manner, all water must pass through the limestone to escape from the mine. As acid water passes through the seal, it is partially neutralized and the resulting precipitation products from neutralization (such as calcium sulfate, ferric hydroxide, etc.) tend to fill voids between the stone and thus retard flow through the seal. Eventually, precipitates should completely plug the seal. Until that time, water which does pass through the seal is neutralized and ferric iron and aluminum are removed.

A 'permeable plug' seal was installed in opening number two in September 1969 (Figure 40). A roof fall served as the rear of the seal and 149.7 metric tons of limestone were pneumatically placed into the opening. The limestone was 85 percent ASSHO #8 (76 percent between 3/8 and 4 mesh) and 15 percent rock dust (approximately 200 mesh). The top of the seal was then grouted to the mine roof using approximately 2.8 m^3 of cement slurry.

As in seal number one, a pitot tube was installed to monitor water depth behind the seal and to allow water samples to be taken.

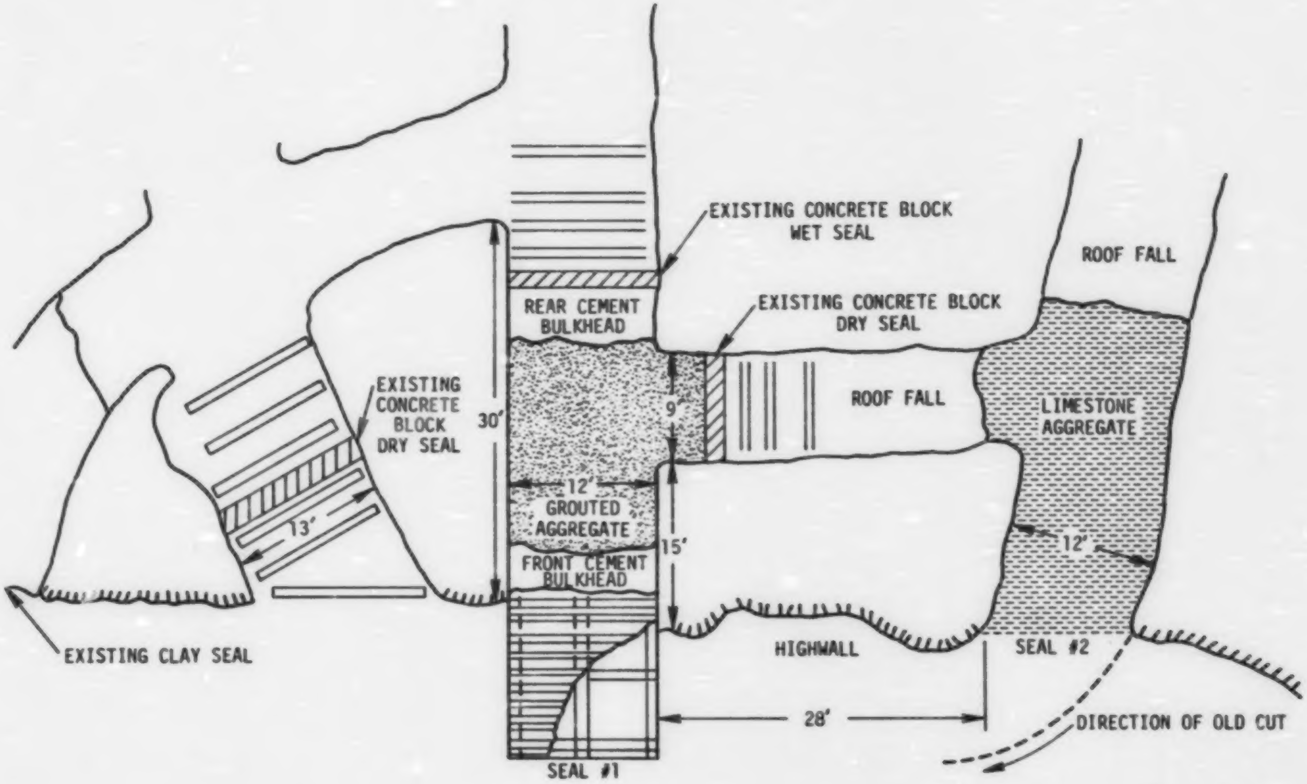

EXISTING CONCRETE BLOCK WET SEAL
EXISTING CONCRETE BLOCK DRY SEAL
ROOF FALL
ROOF FALL
LIMESTONE AGGREGATE
REAR CEMENT BULKHEAD
EXISTING CONCRETE BLOCK DRY SEAL
30'
9'
12'
GROUTED AGGREGATE
FRONT CEMENT BULKHEAD
15'
13'
12'
EXISTING CLAY SEAL
HIGHWALL
SEAL #2
28'
DIRECTION OF OLD CUT
SEAL #1

Figure 40. Plan view of remedial construction - mine No. RT5-2.[a]

[a] To convert feet to meters multiply by 0.305

Water level behind seal number two increased from 0 to 1.6 m within 15 days after seal completion (22). Slow increases over the next three months brought the head to 1.95 m where it remained. No leaks were observed at seal number one. However, the water was not to the roof of the mine at this height and it must be assumed that the pool was draining off in another direction. Mine maps of the area were not accurate enough to reliably ascertain the direction of flow due to localized dips in the area.

To date, the limestone permeable plug seal has been dramatically effective. Flow from RT5-2, which averaged 5.4×10^{-3} m^3/s for 22 months prior to sealing has been reduced to 3.09×10^{-4} m^3/s since sealing for a 94 percent reduction in flow.

Significant improvements have also occurred in water quality and the effluent now exceeds Pennsylvania's discharge standards except for iron concentration. The main questions remaining to be answered are:

1. Longevity of seal number one?
2. Duration of neutralizing capability of seal number two?
3. Effects of reaction on seal two's strength?
4. How much pressure can either seal withstand?

Halliburton reported the costs of both seals to be:

	Site preparation	Material	Equipment & Operators	Total cost
Seal #1	$1079.00	N.A.	N.A.	$9463.00
Seal #2	$3447.00	$1696.00	$3320.00	$8453.00

BUREAU OF SPORT FISHERIES AND WILDLIFE STUDY

In April 1967, the Bureau of Sport Fisheries and Wildlife (BSFW) chose a one-fourth acre strip mine pond in the project area to demonstrate the potential of establishing a fish habitat (23). The inital pH of the pond water was pH 4.2. Application of approximately 100 kilograms of agricultural lime increased the pH to 6.6 and allowed successful stocking of rainbow trout. After two months, the pH had dropped to pH 5.0 due to a continual acid seepage. An additional 100 kilograms of hydrated lime were added and increased the pond pH to 6.0. Survival of trout at that time was acceptable but due to heavy fishing determination of a survival rate was not meaningful. It was concluded from this study that ponds of this type (i.e., slightly acid, low volume acid inflow) can be used for fish habitats by simply using lime to increase pH to acceptable limits. Periodic lime reapplications will be necessary to maintain acceptable conditions but the expense of such treatment is very low in comparison with the benefits.

Termination of construction curtailed plans to install several such ponds in the construction area.

Beginning in 1964, the Bureau of Sport Fisheries and Wildlife had conducted fish population surveys at strategic points in and outside the project area where improvements in water quality due to reclamation would be indicated also by changes in fish population. Again, this approach was from a watershed basis and project termination invalidated use of this data. However, up to termination, no population improvements due to reclamation had occurred.

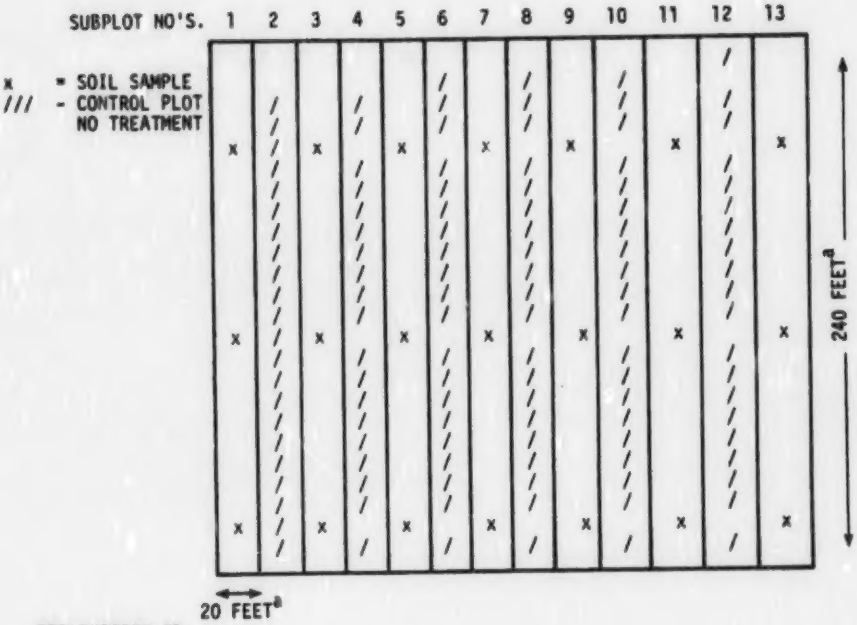
Attempts to re-establish Brook trout in Flatbush Run, a relatively acid-free tributary, were only partially successful due to pollution from gas well brine.

TREATMENT AND REVEGETATION OF TEST PLOTS ON RECLAIMED SURFACE MINES

In August 1969 a study was initiated to determine the effect of various types of soil treatment applied to reclaimed surface mines (24). In Work Area 10, two 56.6 hectare plots consisting of 13 subplots were laid out. Each subplot was approximately 6.1 m wide and 73.2 m long. Secondary sewage sludge, lime, and fertilizer were applied alone and in various combinations to alternate subplots. Design of plots and instruction for treating are shown in Figure 41.

Soil samples were collected and analyzed in August 1969. Table 44 indicates lime requirements expressed for each composite sample collected on the subplots. Secondary sewage sludge samples (from Elkins plant) were collected from the sludge tanker prior to application of liquid sludge to designated plots. Chemical analyses of the sludge indicated the following: pH - 6.9; conductance (μmhos/cm) - 1883; alkalinity (mg/l as $CaCO_3$) - 1400; dissolved solids (mg/l) - 9099.7. Liquid secondary sewage sludge was hauled by a tanker truck to the areas and dumped. Lime and fertilizer were spread on designated subplots by hand or by truck.

Based on previous experience (Project 1) and on recommendations by the Soil Conservation Service, the most suitable types of grass were planted by a hand seeder on Plots 1 and 2 in March 1970 and again on Plot 1 in September 1970. The types and amounts of grass ploted were as follows:


SUBPLOT NO'S.
1
2
3
4
5
6
7
8
9
10
11
12
13
x = SOIL SAMPLE
/// - CONTROL PLOT NO TREATMENT
240 FEET[a]
20 FEET[a]

APPLICATION #1 OCTOBER, 1969							
SLUDGE - WET (TRUCK LOADS)	2	0	0	0	6	3	2
LIME (LB)[b]	0	600^{*}	0	250^{**}	0	0	0
FERTILIZER (LB)[b]	110^{+}	110^{+}	110^{+}	0	0	0	0
APPLICATION #2 JULY 1970							
SLUDGE (DRIED-INCHES)[c]	2	0	0	0	6	3	2
LIME (LB)[b]	0	450^{+}	0	500^{++}	0	0	0
FERTILIZER (LB)[b]	110^{+}	110^{+}	110^{+}	0	0	0	0
APPLICATION RATE (TON/ACRE)[d]	6^{*}	$1\ 1/4^{**}$	$1/2^{+}$	4^{+}	$2\ 1/2^{++}$		

[a] To convert feet to meters multiply by 0.305.

[b] To convert pounds to kilograms multiply by 0.4536.

[c] To convert inches to centimeters multiply by 2.54.

[d] To convert tons/acre to metric tons/hectare multiply by 0.367.

Figure 41. Treatment of reclaimed strip mine - Plots 1 and 2.

TABLE 44. SOIL ANALYSES OF SEWAGE SLUDGE PLOTS BEFORE AND AFTER INITIAL APPLICATION

Sample number	pH				Conductance, µmhos/cm				Lime requirements, lb/acre[a]			
	Plot #1		Plot #2		Plot #1		Plot #2		Plot #1		Plot #2	
	Before application #1[c]	After application #1[d]	Before application #1[c]	After application #1[d]	Before application #1[c]	After application #1[d]	Before application #1[c]	After application #1[d]	Before application #1[c]	After application #1[d]	Before application #1[c]	After application #1[d]
1	3.0	3.9	3.1	3.3	700	180	330	270				
2	3.0	3.6	2.8	4.0	750	270	1400	240				
3	3.0	3.8	3.1	4.1	360	220	700	230				
Composite[b] 1	3.0	3.4	3.0	3.7	660	280	900	250	8650.0	112.0	9863.0	1000.0
1	2.9	3.2	2.9	3.5	920	400	1000	320				
2	3.5	3.7	3.4	3.5	450	470	1650	600				
3	2.9	3.0	4.1	5.2	750	370	700	550				
Composite 3	3.0	3.4	3.3	4.5	820	350	1300	400	6113.0	4000.0	11900.0	2380.0
1	3.0	3.2	3.0	4.4	570	480	900	200				
2	3.1	4.0	3.0	4.4	700	210	1000	1100				
3	3.0	3.5	3.9	3.2	550	200	630	500				
Composite 5	3.0	3.0	3.2	3.2	660	270	840	1200	5988.0	4750.0	9375.0	1880.0
1	3.1	3.3	4.0	4.7	400	270	130	190				
2	3.0	3.5	3.3	3.2	410	320	1600	1100				
3	3.0	3.1	3.1	4.3	350	360	1000	400				
Composite 7	3.0	3.2	3.4	3.8	330	360	1100	370	175.0	5120.0	9550.0	1750.0
1	3.2	3.2	3.2	2.9	380	300	750	700				
2	3.3	3.5	4.6	3.0	280	190	1250	1500				
3	3.1	3.0	3.4	3.2	340	470	660	480				
Composite 9	3.0	3.3	3.6	3.2	360	300	800	650	162.5	5350.0	8063.0	7100.0
1	3.0	3.0	3.3	3.1	940	390	440	470				
2	3.1	3.8	3.2	4.2	380	180	460	1300				
3	3.2	3.0	3.8	4.9	240	650	330	320				
Composite 11	3.1	3.2	3.3	3.9	580	320	300	1000	3463	4380.0	6113.0	1630.0
1	2.8	3.3	3.4	4.6	940	370	250	190				
2	2.9	3.4	3.4	2.9	560	270	170	1400				
3	3.1	3.4	3.8	3.4	280	230	250	360				
Composite 13	2.8	3.5	3.5	3.5	900	330	270	550	2538	4450.0	10888.0	5990.0

[a] To convert lb/acre to Kg/hectare multiply by 1.11.

[b] Composites represent subplots, e.g., composite #1 = subplot #1.

[c] October 1969.

[d] July 15, 1970.

Type of Grass	Application Rate[a]
Birdsfoot trefoil	10 lb/acre
Weeping love grass	5 lb/acre
Tall fescue	5 lb/acre
Rye grass	5 lb/acre
Bluegrass	5 lb/acre

[a] To convert lb/acre to Kg/hectare multiply by 1.11.

Because of little or no growth after initial treatment with lime, fertilizer, and liquid sludge, soil samples were again taken on subplots in Plots 1 and 2 to determine the pH and acidity of the soil (Table 44). Based on the chemistry of the soils, additional treatment was applied to Plot 1 as follows: Lime was applied by hand to designated subplots on the basis of their requirements. Fertilizer was also applied by hand to designated subplots at the same rate as previously. Dried sludge was applied to the surface of designated subplots at depths of 5, 8, and 15 cm. Approximately 5.4 metric tons of dried sludge was applied to subplots 1 and 13, 9.7 metric tons to subplot 11, and 16.3 metric tons to subplot 9. Plot 2 was not treated a second time due to unavailability of dried sludge.

Based on the results of the studies described above, it was concluded that the soil in the subplots contains toxic material evidenced by chemical analyses performed on samples collected at these experimental plots. Low pH readings and high lime requirements varied considerably in each subplot which indicates "hot spots" exist in rather small areas. These hot spots contain acid-forming pyritic material resulting from improper separation of spoil and overburden during the strip mining process. Lime requirements continued to be high based on samples analyzed after treatment (Table 44).

Liquid sludge applied to designated subplots in October 1969 was not successful in treating the soil due to extensive runoff during periods of rainfall. These plots were laid out on slopes varying from 4 to 6 percent and were subject to rill erosion.

A combination of lime and fertilizer applied on various subplots within Plots 1 and 2 was unsuccessful in treating and stabilizing these soils to yield grass cover. Inspection and evaluation of these plots were made by the Soil Conservation Service in May 1970 after initial seeding and again in July 1971. Plot 1 was treated twice during the period of study and indicates some grass growth in subplots treated with various applications of sludge after the second application in July 1970.

Inspections of Plot 1 in July 1971 showed a minimum cover of 5 cm of dried sludge yielded a grass cover of 10 to 30 percent in subplots 1 and 13. Treatment of 8 cm of dried sludge yielded a grass cover of about 30 percent in subplot 11. Maximum coverage of 15 cm yielded a 75 percent grass cover in subplot 9.

Minimum grass coverage was noted at the upper end of the subplots. The most predominant grasses found on these plots were tall fescue and rye grass. Weeping love grass and bluegrass grew sparsely in the vegetated areas. Little or no birdsfoot trefoil was found in these areas.

In summary, the following comments were made:

1. Soil analyses taken before and after treatment indicate that various subplots still contain considerable acid in the soil.
2. "Hot spots" throughout the subplots indicate that acid-bearing pyritic material was not separated from the top soil during strip mining and reclamation.
3. Lime and fertilizer did not bring the soil to desired fertility to produce grass cover.
4. Application of liquid secondary sludge to the surface of the plots was unsuccessful in treating the soil for revegetation.
5. Liquid sludges ran off sloped areas as a result of rainfall and rill erosion.
6. Maximum application of dried sludges yields grass cover of 75 percent.
7. Climatic conditions and rill erosion readily broke up the massive cover of dried sludge exposing the root system, thus killing the grass.
8. Kentucky 31 tall fescue was found to be the most successful vegetative cover on the test plots.

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GLOSSARY

Abandoned Mine - A mine that is not producing any mineral and will not continue or resume operation.

Abatement - The lessening of pollution effects.

Acid - Any of various typically water-soluble and sour compounds that are capable of reacting with a base to form a salt, that redden litmus, that are hydrogen containing molecules or ions able to give up a proton to a base.

Acidity - A measure of the extent to which a solution is acid. Usually measured by titrating with a base to a specific end point.

Acid Mine Drainage - Any acidic water draining or flowing on, or having drained or flowed off, any area of land affected by mining.

Acre-Foot - The quantity of water that would cover an area of one acre, one foot deep.

Alkaline - Having the qualities of a base (i.e., a pH above 7).

Alkalinity - A measure of the capacity to neutralize acids.

Alluvial, Alluvium - Sedimentary (clay, silt, gravel, sand, or other rock) materials transported by flowing water and deposited in comparatively recent geologic time as sorted or semisorted sediments in river beds, estuaries and flood plains, on lakes, shores, and in fans at base of mountain slopes.

Anticline - A configuration of folded stratified rocks in which the rocks dip in two directions away from a crest or fold axis.

Aquiclude (Barrier) - A porous formation that absorbs water slowly but will not transmit it fast enough to furnish an appreciable supply for a well or spring.

Backfilling - The transfer of previously moved material back into an excavation such as mine, ditch, or against a constructed object.

Contour backfill: Material is placed back into the excavation and graded to a slope approximating the original topography.

Pasture backfill: Material is placed back into the excavation and graded to an almost level slope. For this project slope was away from highwall.

Barrier - Portions of the mineral and/or overburden that are left in place during mining.

Bench - The ledge, shelf, table, or terraces formed in the contour method of surface mining.

Benthic - Of pertaining to, or living on the bottom of a body of water.

Borehole - A hole formed with a drill, auger, or other tools for exploring strata in search of minerals for water supply, for blasting purposes, for proving the position of old workings, faults, and for releasing accumulations of gas or water.

Chert - Very hard glassy mineral, chiefly silica.

Conglomerate - A cemented clastic rock containing rounded fragments of gravel or pebble size.

Deep Mine - An underground mine.

Dip - The amount of inclination in degrees of a mineral seam or rock bedding plane from the horizontal. True dip is measured perpendicular to the strike of the bed.

Downdip - Lying down-slope along an inclined mineral seam or rock bedding plane.

Drift - A horizontal or near horizontal passage underground which follows a vein and may be driven from the surface.

Eluvial - A residual ore deposit almost formed in situ but mostly displaced by creep.

Fault - A fracture along which there has been displacement of the two sides relative to one another parallel to the fracture.

Fracture - A break in a rock formation due to intense folding or faulting.

Gob Piles - The refuse or waste left after mining.

Highwall - The exposed vertical or near-vertical wall associated with a strip or area surface mine.

Hydrostatic Head - The pressure exerted by a column of fluid usually expressed in kilograms per square meter (lb/sq in).

Inactive Mine - A mine that is not producing any mineral but may continue or resume operation in the future.

mg/l - Abbreviation for milligrams per liter which is a weight volume ratio commonly used in water quality analysis. It expresses the weight in milligrams of a substance occurring in one liter of liquid.

Mine Seals - A structure built in the portal of an underground mine to control the flow of water or air.

Dry seal: A solid blockage to prevent movement of air and/or water into or out of a mine, but does not build up a head of water.

Wet Seal: A blockage that allows water to escape from a mine but prevents air from entering.

Hydraulic Seal (Bulkhead): Like a dry seal, but will create a head of water inside the mine.

Clay Seal: A dry seal made of clay.

Mine Spoil - The overburden waste material removed or displaced from a surface mining operation that is not considered a useful product.

Outcrop - The part of a rock formation that appears at the surface of the ground.

Outslope - The slope formed on the outer edge of a spoil disposal area.

Periphytin - Sessile biotal components of a fresh-water ecosystem.

Permeability - The measure of the ability of a material to transmit underground water.

pH - The negative logarithm of the hydrogen-ion activity which denotes the degree of acidity or of basicity of a solution. Acidity increases with decreasing values below 7 and basicity increases with increasing values above 7.

Pit - Any mine, quarry or excavation area worked by the open-cut method to obtain material of value.

Pollution Load - The amount of pollutants that a transporting stream carries during a given period of time (usually expressed as kg/day).

Reclamation - The procedures by which a disturbed area can be reworked to make it productive, useful, or aesthetically pleasing.

Regrading - The movement of earth over a surface or depression to change the shape of the land surface.

Sediment - Solid material settled from suspension in a liquid medium.

Shaft - An excavation of limited area compared with its depth made for mineral exploration, or for lowering or raising men and materials, removal of ore or water, and for ventilation purposes in underground mining.

Slope - An inclined shaft for access to a mineral seam usually developed where the seam is situated at distance beyond the outcrop.

Subsidence - A sinking down of part of the earth's crust.

Syncline - A configuration of folded stratified rocks in which the rocks dip downward from opposite directions to come together in a trough.

Underground Mining - Removal of the mineral being mined without the disturbance of the surface (as distinguished from surface mining).

Updip - Lying up-slope along an inclined mineral seam or rock bedding plane.

Urethane Foam - A rigid, cellular, acid resistant foam that is formed by mixing isocyanate and a polyether polyol containing a halogenated hydrocarbon agent which may be used to protect mining and pollution abatement equipment and structures.

METRIC CONVERSION FOR APPENDIX A

To Convert	To	Multiply By
Acres	Hectares	4.047×10^{-1}
Cubic feet	Cu. meters	2.832×10^{-2}
Cubic feet/min.	Cu cms/sec	4.72×10^{2}
Cubic yards	Cu. meters	7.646×10^{-1}
Feet	Meters	3.048×10^{-1}
Gallons	Cu. meters	3.785×10^{-3}
Inches	Centimeters	2.540
Miles (statute)	Kilometers	1.609
Pounds	Kilograms	4.536×10^{-1}
Tons (short)	Tons (metric)	9.078×10^{-1}

APPENDIX A

DETAILED INFORMATION FOR SUBWATERSHEDS

The project site was divided into 45 work areas, each subdivided further into smaller units referred to as subareas. Appendix A contains detailed information pertaining to the work areas (designated by number, e.g., Work Area 1, Work Area 2, ...) and subareas (designated by letter, e.g., Subarea A, Subarea B, ...) within the subwatersheds of the project site. The subwatersheds described in Appendix A are illustrated in Figure A-1. The major topics considered for each subwatershed include:

1. Area Description
2. Mining Summary (Blue Book) and Work Area Description
3. Description of Mine Drainage Problem
4. Reclamation Work Performed
5. Cost of Work
6. Results of Reclamation

GRASSY RUN WATERSHED (G-1)

Area Description

The watershed encompasses 1,869 acres* of hilly terrain south and west of Norton, West Virginia (Figure A-2). It is of oval shape, 1.4 miles wide by 2.6 miles long. Grassy Run flows northeast to the Tygart Valley River. The elevation of its mouth is 1,856 feet; its headwaters are at 2,200 feet. At its beginnings, it falls approximately 0.030 ft/ft; its gradient in the lower reaches is 0.015 ft/ft. The town of Norton lies adjacent to Grassy Run, with houses paralleling it for 0.8 miles. In many cases, these private dwellings contributed directly to the pollution load carried by the stream in its lower reaches.

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* As specified by the EPA Project Officer, all units in the Appendices are presented in the English system and a metric conversion table has been provided.

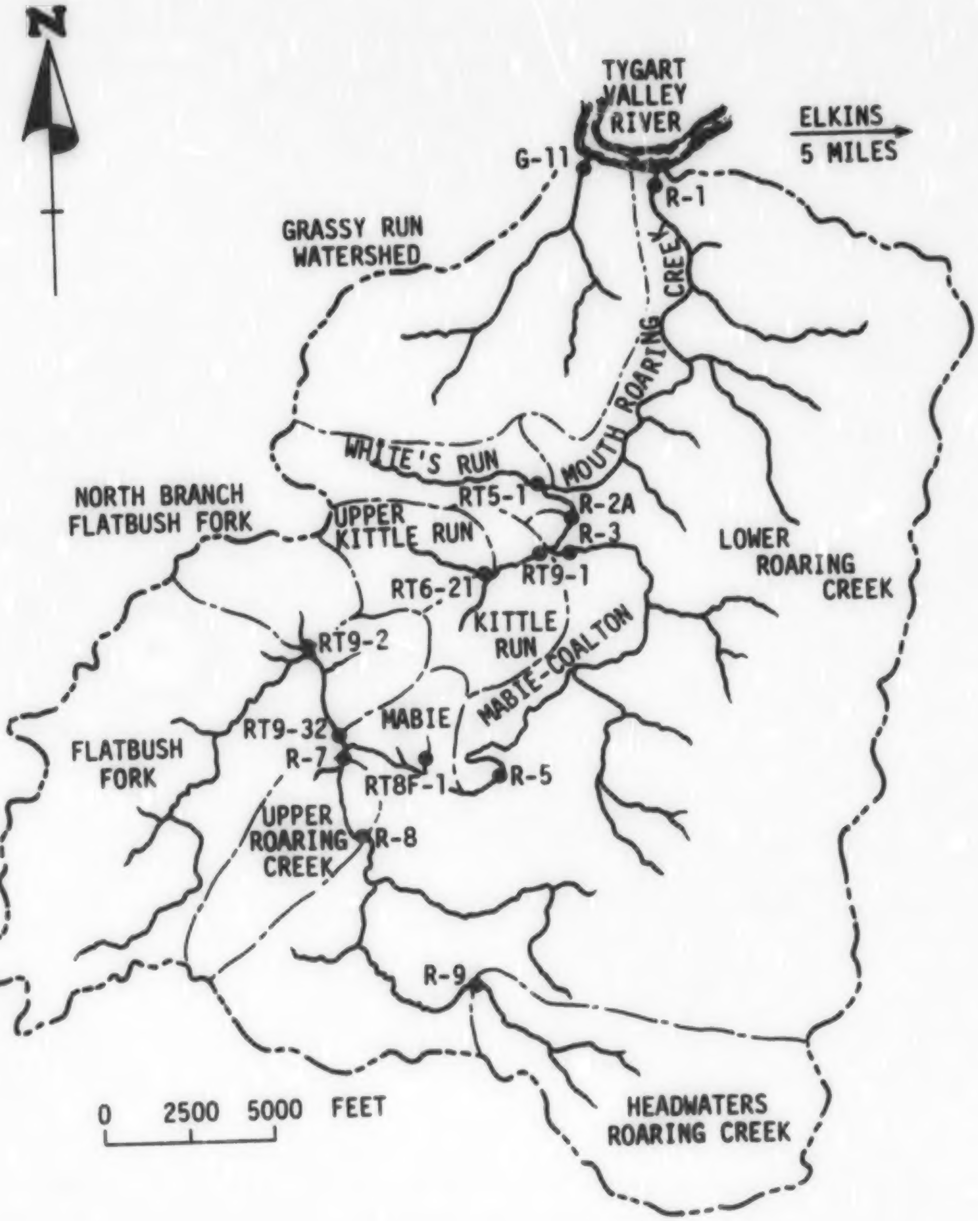
N
TYGART VALLEY RIVER
ELKINS 5 MILES
G-11
R-1
GRASSY RUN WATERSHED
MOUTH ROARING CREEK
WHITE'S RUN
RT5-1
R-2A
R-3
NORTH BRANCH FLATBUSH FORK
UPPER KITTLE RUN
LOWER ROARING CREEK
RT9-1
RT6-21
KITTLE RUN
MABIE-COALTON
RT9-2
MABIE
RT9-32
FLATBUSH FORK
R-7
R-5
RT8F-1
UPPER ROARING CREEK
R-8
R-9
0 2500 5000 FEET
HEADWATERS ROARING CREEK

Figure A-1. Index map to watersheds.

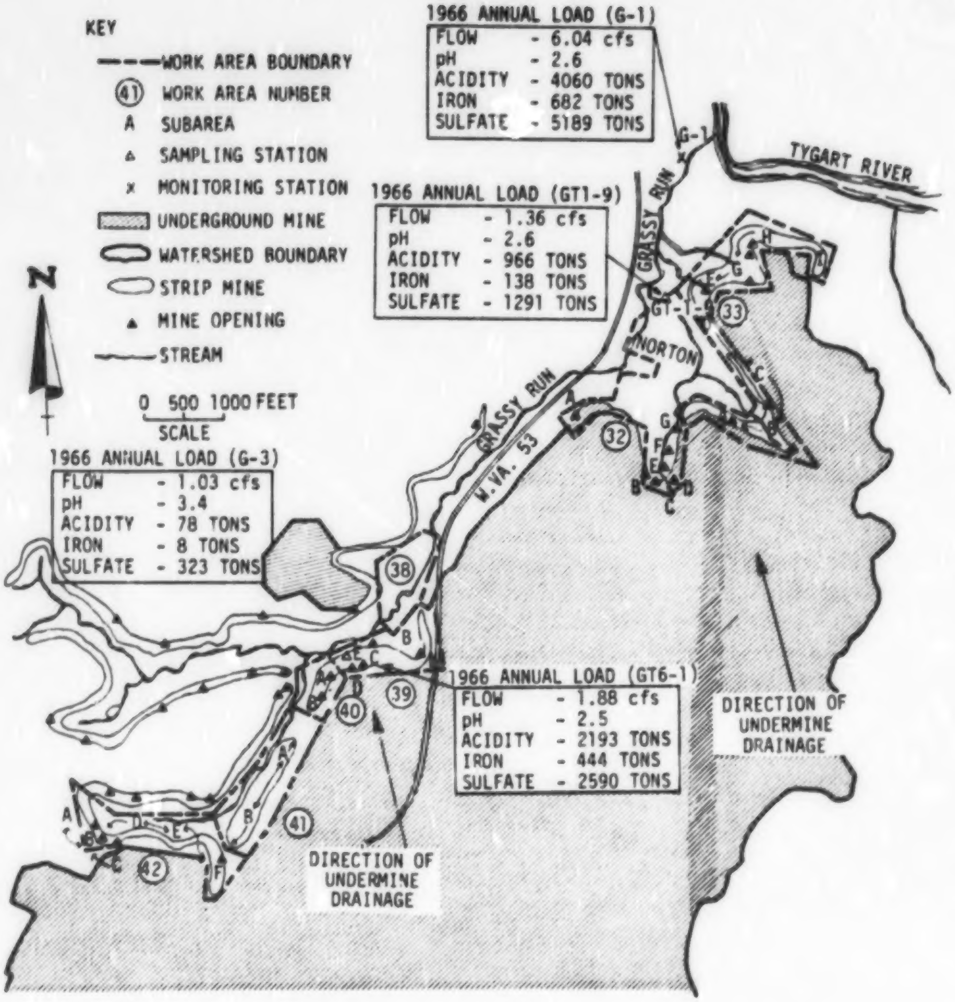
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
x MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
STRIP MINE
MINE OPENING
STREAM
N
0 500 1000 FEET
SCALE
1966 ANNUAL LOAD (G-1)
FLOW - 6.04 cfs
pH - 2.6
ACIDITY - 4060 TONS
IRON - 682 TONS
SULFATE - 5189 TONS
1966 ANNUAL LOAD (GT1-9)
FLOW - 1.36 cfs
pH - 2.6
ACIDITY - 966 TONS
IRON - 138 TONS
SULFATE - 1291 TONS
1966 ANNUAL LOAD (G-3)
FLOW - 1.03 cfs
pH - 3.4
ACIDITY - 78 TONS
IRON - 8 TONS
SULFATE - 323 TONS
1966 ANNUAL LOAD (GT6-1)
FLOW - 1.88 cfs
pH - 2.5
ACIDITY - 2193 TONS
IRON - 444 TONS
SULFATE - 2590 TONS
G-1
TYGART RIVER
GRASSY RUN
GT1-9
NORTON
W.VA. 53
32
33
38
39
40
41
42
DIRECTION OF UNDERMINE DRAINAGE
DIRECTION OF UNDERMINE DRAINAGE

Figure A-2. Grassy Run watershed (G-1).

Mining Summary and Work Area Description[+]

A total of 66.4 acres in the Grassy Run watershed have been strip mined. This represents 3.6 percent of the total. The stripped areas lie near the stream beds where the Kittanning coal crops out. The strip pits account for 28,800 lineal feet of highwall. Mining took place during the late 40's and early 50's, and no reclamation had been accomplished.

Underground mining in the area was extensive. A large abandoned drift mine complex of approximately 3,000 acres lies to the east and south side of the creek. The dip of the coal seam is toward Grassy Run. Smaller mines lie in the west side. Surface mining operations often intercepted the underground mines allowing underground waters to escape. Surface water was entering the underground mine in the Roaring Creek watershed and was being transported to the Grassy Run basin. To illustrate the effect of mining on a watershed Grassy Run was compared to Sand Run, an unmined but otherwise similar watershed. Sand Run had a total runoff of 22.35 inches for the 1965 water year. Grassy Run on the other hand had a total runoff of 34.17 inches. Rainfall for Grassy Run and Sand Run during water year 1965 was 37.80 inches and 39.53 inches, respectively. Even though Sand Run had a slightly higher rainfall, Grassy Run had 53 percent more runoff.

The specific work areas and subareas within this watershed are shown in Figure A-2 and described below.

Work Area 23 - Norton Refuse Pile--

Subarea A--Concealed deep mine opening with small discharge.

Subarea B--No. 1 and No. 2 haulage entry, 15-16 feet wide by 6 feet 8 inches high and concrete-lined for 50 feet. Discharge from portal was 0.53 cfs (GT 1-2).*

Subarea C--Norton No. 1 and No. 2 passing siding. Concrete-lined entry 14 feet by 6 feet 8 inches. Discharge was 0.07 cfs (GT 1-3).

Subarea D--A 60-foot opening along the outcrop discharging 0.29 cfs (GT 1-1).

Subarea E--A 6-foot caved opening discharging 0.002 cfs.

[+] The information discussed under this title throughout Appendix A, refers to work areas and subareas as they originally were prior to any reclamation work.

* Sampling station number - see text.

Subarea F--A 16-foot entry with an 8-foot pillar along the outcrop to the left. Nearly 200 feet of crosscut to the left was in good condition. No surface discharge noted.

Subarea G--A 12-foot entry at the fanhouse discharging 0.28 cfs (GT 1-10).

Work Area 33 - Norton Strip Mine--

Subarea A--A 14-foot caved opening.

Subarea B--A 300-foot poorly graded strip with six or more concealed openings along the highwall. There was a discharge of 0.02 cfs from the southernmost end (GT 1-4).

Subarea C--A 900-foot strip with no backfill. Twelve or more concealed openings along the highwall. There was a discharge of 0.04 cfs from the northern end (GT 1-5).

Subarea D--Road covering possible strip pit.

Subarea E--Mostly concealed dry opening.

Subarea F--Six or more concealed openings which were discharging 0.05 cfs (GT 1-6).

Subarea G--Eight or more concealed openings along a 1,000-foot highwall, had a total discharge of 0.03 cfs (GT 1-7; 1-8).

Subarea H--Seven or more concealed openings along a 600-foot highwall. There was no apparent discharge from these openings.

Subarea I--Coal adjacent to the strip had not been mined because of the cemetery located above the highwall. The eastern half was contour backfilled and the western portion needed only minor grading.

Work Area 38 - Grassy Run Swamp (4 acres)--
Flat area possibly contained 15-20 feet of sawdust and yellowboy.

Work Area 39--

Subarea A--11th right man portal, drainage was not evident (GT 5-1).

Subarea B--Clean, well-drained, 900-foot strip and highwall slough covered the coal seam.

Subarea C--15th right drain, 13 feet wide and 10 feet high. Discharge was 1.9 cfs, measured by Station GT 6-1. This was the major discharge of the watershed.

Subarea D--Caved opening showed no drainage.

Subarea E--A 300-foot strip with auger holes along 50-feet of the highwall. There was no apparent drainage.

Work Area 40 - 15th Right Fanhouse Strip--

Subarea A--Fan drift opening with no discharge.

Subarea B--Concealed entry, had little or no drainage (GT 8-4).

Work Area 41 - Lower GT-8 Strip--

Subarea A--A 300-foot strip, had no apparent drainage. Water ran toward the highwall and any openings were entirely concealed.

Subarea B--A 1,200-foot strip, dirty and poorly graded, there were at least 20 concealed openings along a broken highwall.

Work Area 42 - Upper GT-8 Strip--

Subarea A--Small, partially concealed opening which had only a slight discharge in wet weather.

Subarea B--Small, concealed, dry opening.

Subarea C--Small, concealed, dry opening.

Subarea D--At least six concealed openings along the highwall, with no backfill. Spoil area and cut were covered with trees, shrubs, and grass.

Subarea E--Strip with final cut, was not backfilled. Locust trees were established on the spoil and a pool was formed at the west end (GT 8-3).

Subarea F--Concealed opening in the highwall, had no drainage.

Description of Mine Drainage Problem

At its mouth, Grassy Run contained 3,497, 3,715, and 3,891 tons of acidity per year during the prereclamation years of 1964, 1965, and 1966, respectively. The pH varied from 2.5 to 2.8 (Table A-1 and A-2). The major sources of pollution were

TABLE A-1. SUMMARY OF QUARTERLY DATA FOR STATION G-1, MOUTH OF GRASSY RUN

Quarter	Flow in cfs				pH value			
	1	2	3	4	1	2	3	4
1964	8.50	9.36	1.75	3.37	2.8	2.9	2.7	2.8
1965	13.66	10.45	1.40	1.08	2.8	2.6	2.6	2.6
1966	8.18	9.19	2.13	4.27	2.6	2.5	2.5	2.6
1967	11.12	12.59	2.61	6.84	2.7	2.7	2.7	-
1968	10.51	9.88	2.78	4.93	2.8	2.9	2.8	2.8
1969	9.35	7.51	3.86	5.58	2.7	2.7	2.7	2.8
1970	11.10	10.31	5.26	7.40	2.7	2.6	2.7	2.8
1971	16.00	8.93	6.60	8.00	2.9	2.8	2.8	2.6
	Specific conductance in μmhos/cm							
1964	1525	1747	2092	1844				
1965	1484	1504	1741	1531				
1966	1487	1569	1925	1694				
1967	1491	1352	1633	-				
1968	1315	1025	1286	953				
1969	1133	1325	1216	1260				
1970	1283	1433	1466	1016				
1971	948	1700	1133	1400				
	Acidity							
	Load in tons				Concentration in mg/l			
1964	1417	1195	319	566	680	583	743	690
1965	1841	1457	238	179	551	570	712	679
1966	1317	1532	375	667	661	686	724	659
1967	2734	1526	354	-	618	499	557	-
1968	1430	899	305	474	556	372	450	395
1969	1102	944	385	626	484	514	434	459
1970	1165	1717	649	794	413	463	504	438
1971	1516	1064	586	861	391	491	366	444
	Total Iron							
	Load in tons				Concentration in mg/l			
1964	226	190	52	86	108	93	120	104
1965	296	257	35	27	118	101	104	104
1966	248	288	58	97	125	129	112	93
1967	543	277	60	-	123	91	96	-
1968	321	170	45	81	125	71	65	67
1969	235	229	66	143	103	125	74	105
1970	256	212	117	194	95	84	92	110
1971	373	181	102	192	96	83	64	99

(continued)

TABLE A-1 (continued).

Quarter Year	Sulfate							
	Load in tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
1964	2001	1796	535	885	960	876	1243	1080
1965	3052	2359	356	247	913	923	1043	941
1966	1657	1857	501	894	832	836	965	857
1967	3489	2099	524	-	789	686	824	-
1968	1955	1304	390	677	760	540	577	563
1969	1521	1229	556	1066	668	668	638	782
1970	1863	2169	1229	1176	688	862	955	649
1971	2380	1291	598	1620	613	596	373	835
	Hardness							
	Load in tons				Concentration in mg/l			
1964	775	849	243	426	372	414	564	518
1965	1185	759	174	117	354	375	509	443
1966	707	825	234	441	335	369	450	422
1967	1497	954	271	-	338	312	426	-
1968	827	617	226	373	321	255	334	310
1969	967	984	353	689	424	535	397	507
1970	1063	972	630	984	392	386	489	543
1971	1622	805	-	812	418	372	-	418
	Calcium							
	Load in tons				Concentration in mg/l			
1964	-	-	-	-	-	-	-	-
1965	-	715	112	83	-	280	330	316
1966	496	563	156	283	249	252	300	271
1967	987	633	183	-	224	207	287	-
1968	630	439	155	253	245	182	230	210
1969	668	674	234	505	293	367	263	370
1970	691	705	464	559	255	280	360	309
1971	1034	689	384	517	267	318	339	266
	Aluminum							
	Load in tons				Concentration in mg/l			
1964	-	-	-	-	-	-	-	-
1965	-	128	14	11	-	50	41	42
1966	61	74	20	28	31	33	39	27
1967	128	87	22	-	29	29	35	-
1968	91	54	23	40	36	22	34	34
1969	65	71	25	63	29	39	28	46
1970	91	51	47	76	34	20	38	42
1971	124	68	-	66	32	31	-	34

TABLE A-2. SUMMARY OF ANNUAL DATA FOR STATION G-1, MOUTH OF GRASSY RUN, AND STATION GT 6-1, DRAINWAY DISCHARGE

Year	Rainfall, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station G-1					
Before reclamation					
1965	39.97	1.56	3,715	715	6,314
1966	46.11	1.39	3,891	691	4,909
After reclamation					
1968	44.92	1.66	3,108	617	4,326
1969	51.96	1.54	3,057	673	4,382
1970	46.28	1.98	3,325	779	6,437
1971	45.50	2.33	4,027	848	5,889
Station GT6-1					
Before reclamation					
1965		0.70	2,865	624	4,121
1966		0.44	2,163	445	2,513
After reclamation					
1968		0.63	2,023	500	2,471
1969		0.45	1,523	419	1,915
1970		0.46	1,575	382	2,536
1971		0.38	1,224	315	1,903

the underground discharges at GT 6-1 (Work Area 39C), the mine entries at Norton (Work Areas 22B, C, and D), the refuse pile at Norton, and the large strip mines along upper Grassy Run (these strips and associated auger holes broke into the underground works and allowed water from the underground drainage to seep into the strip pit). The largest single pollution contributor was the old drainway GT 6-1. During the base year 1966, it contributed 31 percent of the flow, 54 percent of the acidity, 65 percent of the iron, and 50 percent of the sulfate found in Grassy Run (Table A-3). The other major sources could not be pinpointed as easily as GT 6-1, because they consisted of complex combinations of underground, surface, and refuse pile discharges. The Norton area as measured at GT 1-9 was one such source which in 1966 contributed 24 percent of the acidity, 20 percent of the iron and 25 percent of the sulfate found in Grassy Run (Table A-4).

The underground discharges that were identified accounted for approximately 50 percent of the acid mine drainage. It was known that a large amount of other acid mine drainage seeps into the strip pit from the underground mines and could be accurately measured.

The natural unpolluted water in Grassy Run, as measured in a stream above any mining, showed that the water had a low buffering capacity and was on the acid side. A typical analysis would be as follows: pH - 5.9, acidity - 7.6 mg/l, alkalinity - 2.0 mg/l, iron - 0.07 mg/l, sulfate - 6.1 mg/l, calcium - 9.5 mg/l, hardness - 9 mg/l, aluminum - 1.2 mg/l, and conductivity - 44 µmhos/cm.

Reclamation Work Performed

Due to termination of the project, no reclamation work was performed in the Grassy Run watershed. The bidding schedule for the project, however, did propose for reclamation of this watershed. The proposed work for the Grassy Run watershed is described below.

Work Area 33 - Norton Strip Mine--

Cleaning and grubbing of area, burial of acid forming and/or carbonaceous material, compaction of backfill along the highwall to prevent infiltration of water, and regrading to a pasture backfill in all but Subareas A and B, which would be graded to contour. An estimated 12,000 cubic yards of compacted backfill and 93,000 cubic yards of excavation would have been required. About 26.6 acres were to be affected.

Work Area 32 - Norton Refuse Pile--

Reconstruction of the gob pile and tipple area. Cleaning and grubbing of strip areas, and backfill to contour. Volumes of material to be moved were not specified because of the

TABLE A-3. SUMMARY OF QUARTERLY DATA FOR STATION GT6-1, UNDERGROUND MINE DRAINWAY

	DRAINWAY							
	Flow in cfs				pH value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	4.79	5.96	0.65	0.47	2.5	2.6	2.6	2.5
1966	2.30	3.10	0.84	1.27	2.5	2.5	2.5	2.5
1967	5.30	4.32	1.13	6.75	2.5	2.6	2.7	2.6
1968	2.66	6.03	1.03	1.01	2.7	2.8	2.7	2.6
1969	3.15	2.52	1.00	0.97	2.6	2.6	2.5	2.6
1970	3.42	2.36	0.79	1.23	2.5	2.5	2.6	2.6
1971	3.15	1.54	0.78	1.00				
	Specific conductance in µmhos/cm							
1965	2383	1896	2045	2236				
1966	2381	2162	2375	2530				
1967	2278	1904	1953	1920				
1968	1666	1523	1655	1587				
1969	1691	1750	1833	1823				
1970	1933	1800	1883	1700				
1971	1400	1600	1900	2033				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	1408	1158	136	123	1199	793	856	1080
1966	736	693	225	409	1303	1041	1085	1309
1967	1495	877	226	1615	1149	827	816	976
1968	565	1029	187	242	866	696	737	899
1969	652	461	215	195	843	745	879	824
1970	703	449	157	266	839	779	806	885
1971	665	241	109	209	870	645	574	869
	Total Iron							
	Load in tons				Concentration in mg/l			
1965	318	252	28	26	271	173	175	224
1966	152	172	47	74	269	226	227	236
1967	315	193	53	397	242	182	190	240
1968	131	271	38	60	200	183	150	223
1969	172	147	46	52	222	238	188	220
1970	156	94	39	93	187	163	202	310
1971	174	50	28	63	228	134	145	263

(continued)

TABLE A-3 (continued).

Quarter	Sulfate							
	Load in tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
Year								
1965	1990	1771	199	161	1695	1212	1250	1407
1966	804	979	272	458	1423	1285	1314	1465
1967	1755	1079	307	2144	1349	1018	1110	1295
1968	644	1317	223	287	987	890	882	1062
1969	805	551	268	291	1040	892	1053	1228
1970	1073	730	278	455	1280	1263	1430	1513
1971	964	330	171	438	1262	884	900	1824
	Hardness							
	Load in tons				Concentration in mg/l			
1965	634	644	92	69	539	441	579	601
1966	307	357	114	213	542	468	548	682
1967	668	444	135	837	513	419	488	505
1968	338	514	110	140	517	347	434	519
1969	415	377	137	146	536	610	557	615
1970	515	316	135	246	618	548	695	817
1971	496	189	-	167	649	505	-	697
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	-	66	49	-	-	416	428
1966	218	249	80	149	386	327	387	477
1967	453	306	93	566	348	288	335	342
1968	220	367	77	95	337	248	303	353
1969	277	268	93	97	358	433	378	408
1970	344	213	88	155	410	368	450	515
1971	277	133	77	106	363	358	405	443
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	-	7	6	-	-	46	54
1966	32	37	12	18	57	48	57	57
1967	68	42	13	91	52	40	47	55
1968	24	73	13	19	37	49	50	69
1969	32	32	12	13	42	52	50	54
1970	49	17	12	24	59	30	61	79
1971	37	16	-	18	49	44	-	74

TABLE A-4. SUMMARY OF QUARTERLY DATA FOR STATION GT1-9, UNDERGROUND DISCHARGE

Quarter	Flow in cfs				pH Value			
	1	2	3	4	1	2	3	4
Year								
1964	-	1.93	0.35	0.57	-	2.9	2.6	2.8
1965	3.56	3.66	0.44	0.23	2.8	2.7	2.6	2.6
1966	1.43	2.27	0.59	1.22	2.6	2.6	2.5	2.7
1967	-	2.94	0.74	-	2.8	2.7	2.8	-
1968	2.65	-	-	1.28	2.8	-	-	2.8
1969	2.32	1.65	1.10	1.12	2.8	2.7	2.6	2.8
1970	2.78	1.32	0.47	0.55	2.7	2.6	2.6	2.7
1971	4.25	1.34	2.88	-				

	Specific conductance in μmhos/cm			
1964	-	1860	2205	2130
1965	1527	1625	1976	1944
1966	1804	1802	2186	1837
1967	1668	-	1775	-
1968	1366	-	-	-
1969	1308	1475	1541	1466
1970	1416	1500	1700	1660
1971	933	1360	1466	-

	Acidity							
	Load in tons				Concentration in mg/l			
1964	-	327	68	112	-	691	784	798
1965	461	547	79	43	528	610	725	760
1966	250	410	110	179	715	737	828	601
1967	-	-	108	-	612	-	597	-
1968	314	-	-	121	484	-	-	384
1969	271	207	144	140	476	511	538	509
1970	321	155	67	72	469	478	584	534
1971	406	143	271	-	394	439	388	0

	Total Iron							
	Load in tons				Concentration in mg/l			
1964	-	49	10	15	0	103	115	106
1965	80	87	10	5	91	97	93	91
1966	38	71	16	17	110	127	118	56
1967	-	-	15	-	94	-	81	-
1968	57	-	-	16	87	-	-	52
1969	46	44	19	27	80	110	70	98
1970	51	22	10	16	75	68	85	118
1971	49	23	45	-	48	71	64	-

(continued)

TABLE A-4 (continued).

Quarter Year	Sulfate Load in tons 1	 2	 3	 4	 Concentration in mg/l 1	 2	 3	 4
1964	-	485	117	174	-	1026	1355	1242
1965	842	891	119	64	964	993	1093	1115
1966	323	534	146	259	922	960	1102	867
1967	-	-	165	-	868	-	915	0
1968	394	0	-	185	607	-	-	590
1969	404	272	204	243	710	672	758	883
1970	475	287	128	120	695	887	1122	888
1971	637	208	361	-	618	640	517	-

	Hardness Load in tons				 Concentration in mg/l			
1964	-	231	53	86	-	488	613	615
1965	350	389	62	22	400	433	571	551
1966	154	235	70	182	440	423	528	611
1967	-	-	92	-	443	-	509	-
1968	264	-	-	109	406	-	-	348
1969	277	223	133	163	486	552	493	590
1970	316	128	71	197	463	396	621	1456
1971	463	150	-	-	449	460	-	-

	Calcium Load in tons				 Concentration in mg/l			
1965	-	284	41	22	-	316	378	380
1966	105	156	46	128	301	280	347	428
1967	-	-	63	-	281	-	352	-
1968	-	-	-		-	-	-	-
1969	185	162	86	105	325	402	320	382
1970	204	90	49	59	298	305	430	433
1971	287	98	210	-	278	302	300	-

	Aluminum Load in tons				 Concentration in mg/l			
1965	-	49	6	4	-	54	51	62
1966	15	24	7	10	44	43	53	34
1967	-	-	8	-	13	-	44	-
1968	-	-	-	-	-	-	-	-
1969	17	16	10	14	31	40	37	49
1970	25	7	6	7	36	21	49	55
1971	47	12	-	-	45	36	-	-

unknown extent of the refuse pile, etc. Control measures for the several deep mine openings were not specified because the underground mine was still active.

Work Area 38 - Grassy Run Swamp--
Draining and filling of swamp filled with sawdust, yellowboy, and acid mine drainage. Construction of a new stream channel for Grassy Run. The work required here was not specified because of many unknown features of the swamp, i.e., depth and amount of material in swamp and best location of new streambed. The excavation was estimated at 1,200 cubic yards and the length of channel at 3,000 feet. Size of swamp was 4.0 acres.

Work Area 40 - 15th Right Fanhouse Strip--
One wet and one dry seal were proposed. Extra work to be specified later was included in the bidding schedule for cleaning up gob, old buildings, etc.

Work Area 41 - Lower GT-8 Strip--
To be regraded to a contour backfill. The estimates were 59,000 cubic yards of excavation and 11,000 cubic years for filling subsidence holes. Area to be affected was 10.3 acres.

Work Area 42 - Upper GT-8 Strip--
Nine dry seals and wet seals were recommended. The area was to be graded to a contour backfill. The estimated yardage was 4,500 cubic yards of compacted backfill, 60,000 cubic yards of excavation, and 8,500 cubic yards for subsidence repair. Area to be affected was 13.8 acres.

Cost of Work

There are no costs associated with the Grassy Run watershed since there was no reclamation of this site.

Results of Reclamation

As explained earlier, the project was terminated before any reclamation work could be initiated in Grassy Run watershed. It was believed, though, that reclamation performed in the parts of Roaring Creek watershed which diverted water from the underground mine complex that normally flowed through the mine to Grassy Run, would reduce the flow and possibly the pollution load in Grassy Run. The influence of reclamation in Roaring Creek on pollution improvement in Grassy Run is discussed below.

Table A-2 indicates that the acidity load measured at the mouth of Grassy Run (G-1) improved substantially following reclamation of Roaring Creek watershed. If 1966 is used as a base year (rainfall for 1966 was similar to that of postreclamation years), then reductions of 783 tons (20 percent), 834 tons (21 percent), and 566 tons (15 percent) occurred during 1968, 1969, and 1970, respectively. In 1971 an increase in flow caused an increase of 136 tons of acidity over the base value. Reductions in iron and sulfate were also noted in 1968 and 1969; however they increased to levels above prereclamation in 1970 and 1971. The flow at the mouth of Grassy Run was greater after reclamation than before. This finding is difficult to explain except that it reflects the inherent problem of comparing annual rainfall and runoff data for different years. Quarterly data for this site are presented in Table A-1.

It was believed that the mine discharge at drain tunnel GT 6-1 would possibly reveal the reduction of inflow better than the mouth of Grassy Run, since there would be less influence from outside factors. As seen in Table A-2 acidity and iron levels have decreased, whereas the flow and sulfate levels have remained about the same. Two observations provide some indication that the reclamation work has caused changes in Grassy Run. The underground mines are yielding a smaller percentage of the total flow in Grassy Run, and heavy rainstorms no longer produce extreme peaks in the flow from GT 6-1. It would appear that more time is now required for the water to enter the mine. Thus, the large slugs of acid water have been eliminated.

In summary, it appears that some reduction in acidity has occurred, whereas the reduction of flow, iron, and sulfate is questionable.

HEADWATERS OF ROARING CREEK (R-9)

Area Description

Roaring Creek has its headwaters on Rich Mountain above Sampling Station R-9 (see Figure A-1). The watershed is 2.5 miles long by 1.1 miles wide and contains 1440 acres. Station R-9 lies at elevation 2,450 ft. while Rich Mountain rises to 3,662 ft. in the southeast portion. The mainstem of the creek flows 2.4 miles through the watershed, falling at the rate of 0.083 ft/ft for the first half of its length and 0.026 ft/ft as it leaves the area. The drainage basin is wooded and has very few private dwellings.

Mining Summary and Work Area Description

There were 18.6 acres of surface-mined land in the watershed, accounting for 1.3 percent of the total area. This mining was done in the Sewell coal seam and contributes very little to the pollution load of Roaring Creek. The area contains no underground mines.

Description of Mine Drainage Problem

In these upper reaches of Roaring Creek there was little or no acid mine drainage pollution. Table A-5 shows that the water quality for 1965-1967 was better than any point downstream. Water passing Station R-9 was considered to be typical of natural runoff.

Reclamation Work Performed

There were no major pollution problems associated with the headwaters of Roaring Creek, and therefore reclamation work was not performed in this area.

UPPER ROARING CREEK (R-8 to R-7)

Area Description

The watershed drains into upper Roaring creek above Mabie, and is designated by Stations R-8 to R-7 on Roaring Creek (Figure A-3). It encompasses an area of 582 acres. The stream drops 12 feet between R-8 and R-7 in a distance of 1.0 mile. Roaring Creek meanders considerably and encircles Work Area 31.

Mining Summary and Work Area Description

A total of 89 acres, 15 percent of the watershed, has been surface-mined. Work Area 31 contains 37 acres of strip mining and has been deep-mined extensively. The Demotto strip contains approximately 30 acres and was mined in May-October 1965. It was not reclaimed until 1968. Work Area 26, upper Flatbush Fork strip, contains 24.6 acres, and is partially located in a remote part of the drainage area. It contributes very little pollution to Roaring Creek. Work areas within this watershed are shown in Figure A-3 and described below.

Work Area 26 - Upper Flatbush Fork Strip (7 acres)--

Subarea A--A 16-foot opening in highwall. Only driven 15 feet into solid coal.

Subarea B--A 16-foot opening in highwall. Entry caved 40 feet from portal (RT 6-29 drain), spoil had been leveled, but coal seam was exposed.

Work Area 31 - Mabie Mine Strip (14 acres)--

Subarea C--Nine or more partially concealed openings. Seepage was noted from three.

Subarea D--Eight or more partially concealed openings were noted along this highwall. No drainage was noted. The re-

TABLE A-5. SUMMARY OF QUARTERLY DATA FOR STATION R-9, HEADWATERS OF ROARING CREEK

	Flow in cfs				pH value			
Quarter Year	1	2	3	4	1	2	3	4
1965	8.529	4.014	0.093	0.462	5.3	5.6	5.6	4.6
1966	4.449	6.797	0.759	5.471	5.3	5.5	4.8	5.5
1967	10.448	8.020	2.923		5.4	5.6	5.8	-
	Specific conductance in µmhos/cm							
1965	28	25	59	111				
1966	37	33	102	32				
1967	28	31	29	-				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	7	2.4	.06	1.8	3.1	2.4	2.8	15.6
1966	15	12	2	8	14	7	11	6
1967	5	-	2	-	1.8	-	3	-
	Iron							
	Load in tons				Concentration in mg/l			
1965	.4	.4	.01	.03	.2	.4	.5	.3
1966	.1	.3	.1	.8	.08	.2	.8	.6
1967	.6	.2	.07	-	.2	.1	.1	-
	Sulfate							
	Load in tons				Concentration in mg/l			
1965	9	4	0.2	1.4	4	4	8	12
1966	6	9	3	6	5	6	14	4
1967	8	8	3	-	3	4	4	-
	Hardness							
	Load in tons				Concentration in mg/l			
1965	16	6	.3	1.3	7	6	11	11
1966	9	9	4	15	8	5	19	11
1967	14	6	8	-	5	3	11	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	4	.2	.1	-	4	7	7
1966	8	8	2	11	7	5	12	8
1967	11	5	5	-	4	3	7	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	.1	.03	.03	-	.1	2	.2
1966	.3	.4	1	1.2	.2	.2	.5	.8
1967	.5	.2	-	-	.2	.1	-	-

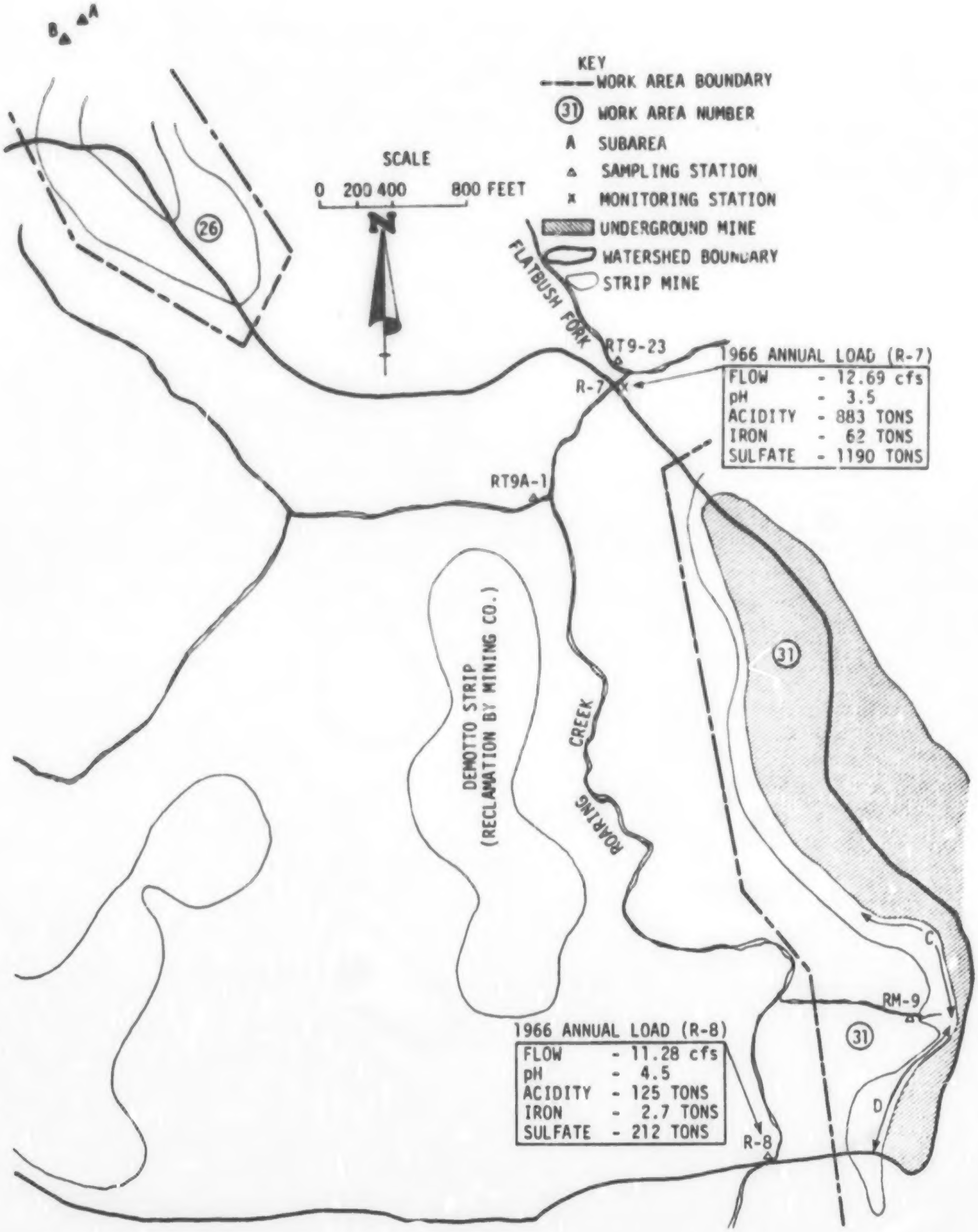
B
A
KEY
WORK AREA BOUNDARY
31 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
STRIP MINE
SCALE
0 200 400 800 FEET
N
26
FLATBUSH FORK
RT9-23
R-7
1966 ANNUAL LOAD (R-7)
FLOW - 12.69 cfs
pH - 3.5
ACIDITY - 883 TONS
IRON - 62 TONS
SULFATE - 1190 TONS
RT9A-1
31
DEMOTTO STRIP
(RECLAMATION BY MINING CO.)
ROARING CREEK
C
RM-9
31
D
1966 ANNUAL LOAD (R-8)
FLOW - 11.28 cfs
pH - 4.5
ACIDITY - 125 TONS
IRON - 2.7 TONS
SULFATE - 212 TONS
R-8

Figure A-3. Upper Roaring Creek (R-8 to R-7).

maining subareas located in Work Area 31, which do not affect this watershed, are reported later in Appendix A (see the Middle Roaring Creek segment).

Description of Mine Drainage Problem

Flow values and water quality at Stations R-8 and R-7 are shown in Tables A-6 and A-7. A water quality summary for Station R-7, showing the various parameters, is presented later in Appendix A (see the Middle Roaring Creek segment). Significant changes in water quality occurred in May and June 1965 as a result of an active strip located in the Mercer seam and operated by the Demotto Coal Company. The pH decreased one unit, and acidity, specific conductance, iron and sulfate increased 200 to 700 percent. Reclamation of this area did not begin until 1968. The area was planted in late 1968 and at this time a second significant change in water quality occurred.

The largest mine drainage from Work Area 31 discharged from RM-9.* Other mining in this watershed contributed little or no mine drainage to Roaring Creek.

Reclamation Work Performed

Except for reclamation done by the Roaring Creek Company on the Demotto strip, no reclamation or mine sealing was performed in this drainage area.

Cost of Work

No construction costs were incurred in the drainage area. Planting of black alder, Japanese larch, tulip poplar, cottonwood, and white oak on 18 acres of Work Area 26 were made at a cost of $103.10/acre. Black alder and white oak are the predominant species, with greater than 65 percent survival.

Results of Reclamation

The greatest mine pollution of Roaring Creek between R-8 and R-7 was contributed by an active strip mine (Demotto strip) operated by the Roaring Creek Coal Company.

Significant changes in concentrations and loads for iron, acidity, and sulfates were detected immediately after reclamation by the coal company in 1968 (Table A-7).

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* The prefix RM is used to designate mine drainage monitoring sites in Work Area 31.

TABLE A-6. SUMMARY OF ANNUAL DATA FOR STATIONS R-7 AND R-8, UPPER ROARING CREEK

Year	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station R-7				
Before reclamation				
1965	2.50	216	17	411
1966	2.99	883	62	1,190
After reclamation				
1968	3.93	834	48	1,255
1969	3.76	775	36	770
1970	3.80	564	35	668
1971[b]	5.97	614	22	560
Station R-8				
Before reclamation				
1965[a]	a	13	0.6	66
1966	2.66	125	2.7	212
After reclamation				
1968	3.48	91	2.1	160
1969	2.49	95	8.5	94
1970	3.04	113	15	136
1971[c]	-	-	-	-

[a] Data not available for first three months of the year.

[b] Data available for first half of the year only.

[c] Data available for first half of the year only.

TABLE A-7. SUMMARY OF QUARTERLY DATA FOR STATION R-8, UPPER ROARING CREEK

	Flow in cfs				pH value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	-	9.578	0.144	0.943	-	4.7	4.4	4.0
1966	12.000	18.129	1.777	13.163	4.5	4.5	3.9	4.5
1967	14.927	20.659	4.322	10.566	4.7	4.6	4.9	4.1
1968	21.376	20.416	0.595	16.726	4.9	4.9	5.0	5.1
1969	11.369	6.699	15.183	8.941	4.9	4.9	4.3	4.8
1970	22.666	11.166	4.166	13.516	4.7	4.6	5.3	5.1
1971	24.75	11.78	-	-	5.0	5.2	0	0

	Specific conductance in µmhos/cm			
1965	-	54	164	194
1966	74	67	159	57
1967	56	59	47	36
1968	40	39	69	63
1969	58	54	60	60
1970	50	67	69	45
1971	42	45	-	-

	Acidity							
	Load in tons				Concentration in mg/l			
1965	-	9	0.2	4	-	3.7	4.7	15.9
1966	50	45	8	22	17	10	19	7
1967	15	25	4	13	4	5	4	5
1968	30	43	0.7	17	6	9	5	4
1969	23	16	34	22	8	10	9	10
1970	64	30	7	12	12	11	7	3.5
1971	12	7	-	-	2.0	2.6	-	0

	Iron							
	Load in tons				Concentration in mg/l			
1965	-	0.5	0.02	0.1	-	0.2	0.6	0.4
1966	0.3	0.8	0.3	1.3	0.1	0.2	0.6	0.4
1967	0.6	2	0.2	0.5	0.2	0.4	0.2	0.2
1968	0.5	0.5	0.1	1	0.1	0.1	0.5	0.3
1969	2	1.5	3	2	0.7	0.9	0.9	1
1970	6	4	1.6	3	1	1.3	1.6	0.9
1971	4	0.6	-	-	0.6	0.2	-	-

(continued)

TABLE A-7 (continued).

	Sulfate							
	Load in tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	-	55	0.6	10	-	23	18	42
1966	53	78	16	65	18	18	36	20
1967	42	54	12	26	12	11	11	10
1968	40	39	2	79	8	8	14	19
1969	30	14	30	20	11	9	8	10
1970	49	33	26	28	9	12	25	8
1971	42	20	0	0	7	7	0	0
	Hardness							
	Load in tons				Concentration in mg/l			
1965	-	34	0.7	7	0	14	20	29
1966	55	62	14	54	18	13	32	16
1967	48	53	19	43	13	10	17	16
1968	54	58	2	66	10	11	15	16
1969	63	23	54	25	22	14	14	11
1970	77	25	16	28	13	9	15	16
1971	84	77	-	-	14	27	-	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	18	0.4	4	0	8	11	17
1966	31	37	8	36	11	9	18	11
1967	29	38	13	26	8	7	12	10
1968	87	33	1.5	32	17	7	10	8
1969	48	14	30	15	17	9	8	7
1970	44	12	9	27	8	4	9	8
1971	36	17	0	0	6	6	-	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	0.8	0.02	0.2	-	0.3	0.4	0.7
1966	2	2	0.4	2	0.6	0.4	0.8	0.7
1967	1	2	0.3	0.4	0.3	0.4	0.2	0.1
1968	9	0.5	0.1	14	1.6	0.1	0.9	3
1969	7	1	5	4	2.6	0.6	1.3	2.0
1970	6	2.7	1	2.8	1	1	0.9	0.8
1971	4	2.3	-	-	0.7	0.8	-	-

NORTH FORK BRANCH FLATBUSH RUN WATERSHED (RT 9-2)

Area Description

The oblong watershed encompasses 605 acres of hilly and rolling land (Figure A-4). Its southern border approximates State Route 53; the northern and western limits parallel US 33. At its most western point, the basin reaches Pumpkintown, West Virginia. King Summit school is located just north of the basin on US 33 in an area containing most of the private dwellings in the watershed. The basin is 1.89 miles long and 0.83 miles across at the widest point. The total length of the main stream is 1.46 miles, falling at the average rate of 0.025 ft/ft from its headwaters. Total relief in the area is 311 feet; the highest point being 2,551 feet above sea level.

Mining Summary and Work Area Description

Strip mining in the watershed during the 40's and 50's disturbed approximately 131 acres (22 percent of land area). This activity left 3000 feet of highwall. To the north and northeast, the strip mines intercept a large underground mine which extends to Norton. Approximately 70 acres of this deep mine underlie the watershed. The strip mines lie on the high side of the Kittanning coal seam, and drainage generally was into the underground mines, since the grading was toward the highwall. Several small underground mines operated from the strip cut, but did not usually have drainage. On the south side of the watershed was a 58-acre two-seam strip mine. One small underground mine was located in the lower Clarion seam. Drainage from this area was into Flatbush Fork.

Work areas within this watershed are shown in Figure A-4 and described below.

Work Area 1 - Flatbush No. 1 Strip (22 acres)--
This strip was backfilled but poorly graded. The acid refuse covering was yielding runoff of pH - 3.2, acidity - 250 mg/l, and iron - 33 mg/l.

Work Area 2 - Flatbush No. 1 Strip Continued (30 acres)--

Subarea A--Old mine opening with about 8 inches of water on the floor. Water seeped into the pit.

Subarea B--Opening to the old underground mine workings with no drainage.

Work Area 3 - Flatbush No. 1 Strip Continued (5 acres)--
This strip was unbackfilled, and excessive acid refuse was exposed on the spoil. An intermittent stream had been intercepted and water was impounded in the highwall cut. Discharge

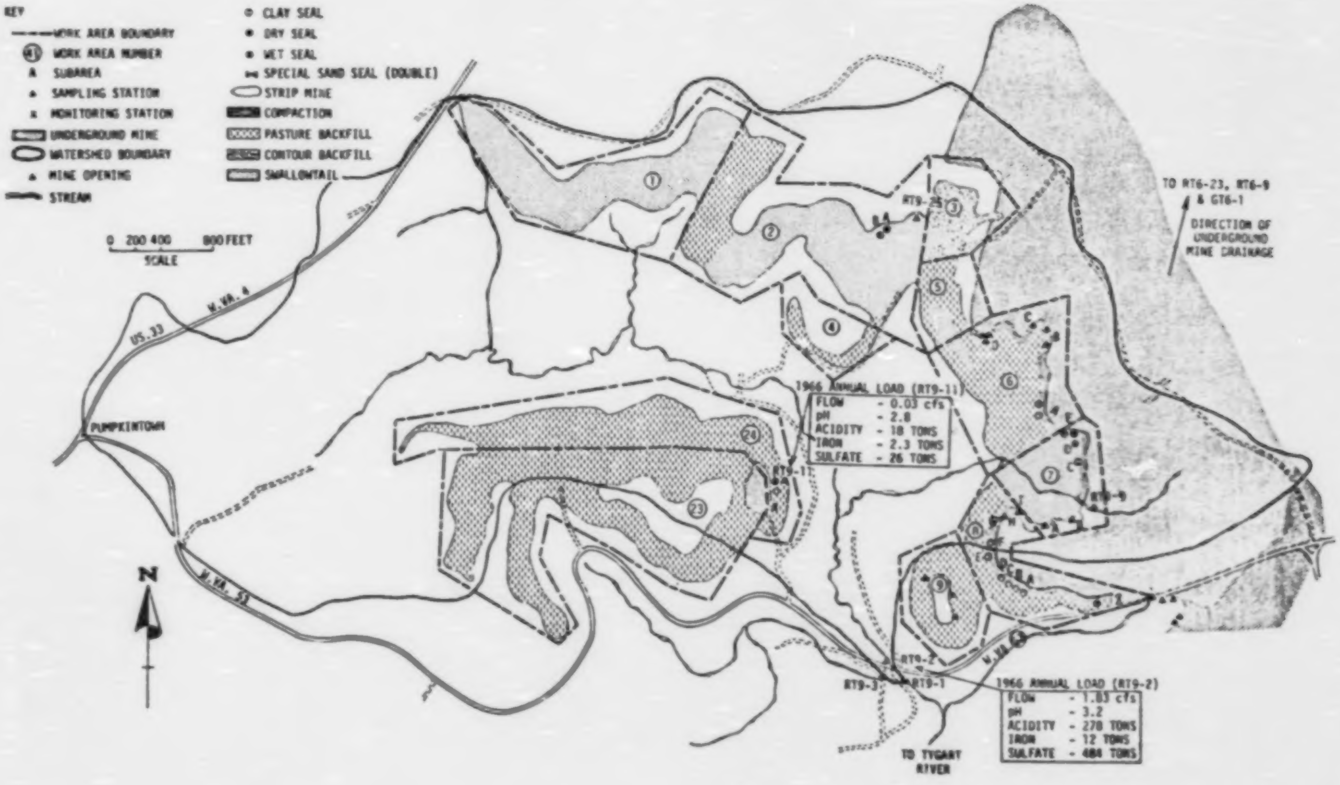
KEY
WORK AREA BOUNDARY
WORK AREA NUMBER
SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 200 400 800 FEET
SCALE
N
PUMPKINTOWN
US. 33
W.VA. 4
W.VA. 51
TO RT6-23, RT6-9
& GT6-1
DIRECTION OF UNDERGROUND MINE DRAINAGE
RT9-23
RT9-11
RT9-9
RT9-2
RT9-3
RT9-1
TO TYGART RIVER
1966 ANNUAL LOAD (RT9-11)
FLOW - 0.03 cfs
pH - 2.8
ACIDITY - 18 TONS
IRON - 2.3 TONS
SULFATE - 26 TONS
1966 ANNUAL LOAD (RT9-2)
FLOW - 1.83 cfs
pH - 3.2
ACIDITY - 278 TONS
IRON - 12 TONS
SULFATE - 484 TONS
①
②
③
④
⑤
⑥
⑦
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Figure A-4. North Branch Flatbush Fork watershed (RT9-2).

(RT 9-6) from the area had a pH - 3.4, acidity - 240 mg/l and iron - 14 mg/l.

Work Area 4 - Prospect Strip (2.1 acres)--
Strip unbackfilled and was on a seam below the Kittanning coal.

Work Area 5 - Flatbush No. 1 Strip Continued (4.3 acres)--
Well-graded and backfilled area with no visible openings.

Work Area 6 - Flatbush No. 1 Strip Continued (11.5 acres)--
The strip pit was unbackfilled, contained acid-producing material and drained towards the highwall.

Subarea A--Two openings to the active Sainato Mine.

Subarea B--Caved opening 16 by 12 feet.

Subarea C--Concealed opening in the highwall.

Subarea D--Three concealed openings in the highwall.

Work Area 7 - Flatbush No. 1 Strip Continued--
The strip was unbackfilled, ungraded, and dirty, with drainage into a large pool impounded next to the highwall.

Subarea A--Concealed opening to mine.

Subarea B--Subsidence area.

Subarea C--Concealed opening with massive caving in the highwall.

Subarea D--A 14-foot mine opening. A siphon hose ran from the pool in the strip into the mine to lower the pool level.

Subarea E--Two 14-foot concealed openings in the highwall.

Work Area 8 - Flatbush No. 1 Strip Continued (3.2 acres)--
Part of Area 8 (Subareas A-E) is in another watershed. These subareas are considered later in the Appendix under the Flatbush Fork watershed segment.

Subarea F--Opening to the mine, with no drainage in or out.

Subarea G--Caved opening in the highwall.

Subarea H--Caved dry opening in the highwall.

Subarea I--Opening into the old workings, with no drainage. The mine was above drainage in the strip pit. The outer spoils had been leveled, but the highwall cut remains unbackfilled. A refuse pile remained near the tipple south of the mine opening.

Work Area 23 - Upper Pumpkintown Road Strip--
This strip, on the Kittanning seams of coal, was completed in the early 1960's. Approximately 50 percent of the operation had been leveled, but none had been graded to expedite runoff. Acid-forming refuse was exposed throughout the spoils. The highwall showed no deep mine openings. Work Areas 23 and 24 contain 58 acres, of which only 44 are in this watershed.

Work Area 24 - Lower Pumpkintown Strip and Strip Mine in Clarion Coal--

Subarea A--Two openings 50 feet apart. Both portals were caved, and yield a combined discharge of about 2 gpm. The mines were flooded behind blockages of iron precipitates on wet leaves. Six small discharges from the strip were noted. Much of the strip had coal spread indiscriminately on the spoil surface. Discharge from RT 9-11, from the underground mine, average flow was 0.035 cfs, pH - 2.8, acidity - 600 mg/l, and iron - 110 mg/l.

Description of Mine Drainage Problem

This watershed exhibits the problems of strip mine drainage almost exclusively. For the base year 1966, the deep mines contributed less than 1 percent of the pollution. Selection of this base year is important in considering the pollution load carried by the stream. The year 1966 was selected rather than 1965 because precipitation conditions in 1966 were similar to those in postconstruction years (Table A-8). Average concentrations of pollutants in the stream for the base year at Station RT 9-2 were as follows: acidity - 169 mg/l, total iron - 4.7 mg/l, sulfate - 297 mg/l, hardness - 188 mg/l, calcium - 99 mg/l, and aluminum - 15 mg/l (Table A-9). Data for Station RT 9-9 represents the quality of natural runoff not affected by mining. This channel was dry most of the year and carried water only during wet seasons or immediately after a storm. For example, in February 1966 the data for RT 9-9 was as follows: pH - 4.5, specific conductance - 112 μmhos/cm, acidity - 11 mg/l, total iron - 0.08 mg/l, sulfate - 24 mg/l, hardness - 20 mg/l, calcium - 14 mg/l, and aluminum - 0.6 mg/l. These data show that the natural runoff was on the acidic side and the water has virtually no buffering capacity.

TABLE A-8. SUMMARY OF ANNUAL DATA FOR STATION RT 9-2, MOUTH OF NORTH BRANCH FLATBUSH FORK

Year	Rain, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Before reclamation					
1965	36.65	0.31	195	6.5	369
1966	44.79	0.43	278	12.0	484
After reclamation					
1968	41.46	0.48	151	8.5	438
1969	42.58	0.38	143	9.0	307
1970	42.60	0.33	117	5.5	255
1971	37.92	0.52	174	8.9	228

Reclamation Work Performed

All of the disturbed lands in this watershed were reclaimed. The reclamation plan was to seal the underground mines to prevent air and water from entering and to reclaim the strip mines to prevent the movement of acid from that source. For bidding purposes, Work Areas 1 - 9 and 23 - 24 were combined. As seen in Table A-10 the estimated excavation in the contract was 717,000 cubic yards. A survey of the area following reclamation revealed that 999,029 cubic yards had been moved. The increase in yardage is partially due to the method of calculation, i.e., original yardage was calculated from maps made from aerial photographs and cross sections superimposed by the consulting engineer. The final yardage was calculated from an on-ground survey and compared to the maps prepared from aerial photographs. More fill than originally estimated was needed in some cases.

The contract called for 16 dry masonry seals to be constructed in Work Areas 1 - 9 and two in Work Area 24. The actual seals constructed are reported in Table A-11. In many cases, it was found that the condition of the underground mine openings made it difficult to install dry seals. In such instances the opening was filled with compacted clay. In other cases, the highwall was in such poor condition that the installation of dry seals would have been a safety hazard, so a compacted backfill was used. In Work Area 24, two dry seals were constructed. Several months later one of these seals failed and a wet seal was constructed as a replacement.

TABLE A-9. SUMMARY OF QUARTERLY DATA FOR STATION RT 9-2, MOUTH OF NORTH BRANCH FLATBUSH FORK

	Flow in cfs				pH value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	3.53	1.43	0.07	0.27	3.4	3.2	3.0	3.1
1966	2.62	2.23	0.53	1.93	3.3	3.2	3.0	3.3
1967	3.53	2.41	0.75	1.42	3.4	3.4	3.3	3.6
1968	2.93	2.82	0.49	1.88	3.6	3.8	3.4	3.6
1969[a]	2.10	1.30	1.04	1.87	3.7	3.5	3.1	3.5
1970[a]	1.93	1.48	0.47	1.71	3.7	3.3	3.4	3.7
1971[a]	3.02	1.21	3.09	1.62	3.8	3.5	3.5	3.6
	Specific conductance in µmhos/cm				Precipitation inches[b]			
1965	602	680	1045	890	11.98[c]	11.05[c]	7.22[c]	6.40[c]
1966	614	644	1034	693	8.40[d]	10.76[d]	16.28[d]	9.35[d]
1967	564	543	738	383	12.55	16.33	15.11	11.59
1968	456	353	673	443	6.63	12.50	11.00	11.33
1969	446	550	526	463	7.11	9.41	17.70	8.36
1970	370	483	608	340	5.91	10.52	14.97	11.20
1971	350	414	403	417	9.06	6.96	16.17	5.73
	Acidity							
	Load in tons				Concentration in mg/l			
1965	122	53	5	15	141	151	271	224
1966	99	80	30	69	155	146	228	146
1967	87	48	27	24	101	88	146	69
1968	63	44	16	28	95	64	124	61
1969	39	37	26	41	76	118	101	90
1970	34	38	14	31	72	104	121	74
1971	32	21	77	44	44	70	103	111
	Total Iron							
	Load in tons				Concentration in mg/l			
1965	5	1	0.1	0.4	5	4	6	6
1966	3	2	2	3	4	3	6	6
1967	5	3	2	2	6	5	9	5
1968	4	2	0.5	2	6	2	4	3
1969	3	1	3	2	5	6	11	4
1970	2	1	0.5	1	3	7	4	5
1971	2	0.8	1.1	5	3	2.7	1.5	12

(continued)

TABLE A-9 (continued).

Quarter Year	Sulfate							
	Load in tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
1965	234	102	9	24	270	292	493	370
1966	163	125	53	143	253	230	405	301
1967	212	117	66	64	246	213	359	183
1968	192	114	35	97	267	165	287	212
1969	91	81	45	90	176	252	177	196
1970	93	64	32	66	197	176	280	155
1971	81	40	51	56	111	136	68	143
	Hardness							
	Load in tons				Concentration in mg/l			
1965	150	66	5	16	173	187	280	239
1966	90	83	33	96	139	152	257	202
1967	134	70	42	45	154	126	230	129
1968	114	58	25	71	158	83	205	154
1969	95	73	64	80	185	228	251	173
1970	62	44	22	70	131	122	189	166
1971	-	-	-	-	-	-	-	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	40	3	9	-	115	165	136
1966	51	45	17	48	79	82	134	101
1967	69	38	24	25	79	69	131	73
1968	65	36	16	38	90	52	131	83
1969	58	103	35	46	114	327	137	99
1970	33	30	15	34	71	82	125	79
1971	46	21	46	29	63	70	62	74
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	6	0.4	1.4	-	16	25	22
1966	8	7	3	7	12	13	19	14
1967	8	4	3	3	10	7	14	8
1968	7	3	2	5	9	5	12	10
1969	5	4	3	3	9	11	11	7
1970	4	2	0.8	4	10	7	9	9
1971	5	0.9	-	0	7	3	-	-

[a] Flow data taken from daily readings

[b] Data taken from Kittle Run raingage #5

[c] Values taken from Elkins Airport and corrected to read as gage 5, by the equation Gage #5 = Airport reading x 1.046

[d] First two quarters only computed from Elkins Airport readings

TABLE A-10. EXCAVATION OF NORTH BRANCH FLATBUSH FORK

	Areas 1 - 9	Areas 23 - 24
Common excavation, cu. yds.		
Contract estimate	403,000	262,000
Actually completed	639,747	348,788
Difference, yards	+236,747	+ 86,788
Subsidence excavation, cu. yds.		
Contract estimate	16,000	0
Actually completed	0	0
Difference, yards	- 16,000	0
Compacted backfill, cu. yds.		
Contract estimate	36,000	0
Actually completed	10,494	0
Difference, yards	- 25,506	0
Total		
Contract estimate	455,000	262,000
Actually completed	650,241	348,788
Difference, yards	+195,241	+ 86,788

TABLE A-11. MINE SEALS CONSTRUCTED IN NORTH BRANCH FLATBUSH FORK

	Area 2	Area 6	Area 7	Area 8[e]	Area 24[f]	Total
Dry seals[a]						
Proposed	2	0	5	9	2	18
Constructed	2	0	3	1	0	6
Wet seals[b]						
Proposed	0	0	0	0	0	0
Constructed	0	0	0	0	1	1
Clay seals[c]						
Proposed	0	0	0	0	0	0
Constructed	0	2	1	2	1	5
Timber and Sand[d]						
Proposed	0	0	0	0	0	0
Constructed	0	0	0	2	0	2

[a] Solid masonry seal to prevent water and air from entering mine.

[b] Solid masonry seal with water trap to prevent air from entering mine but allowing water to exit.

[c] Clay compacted in mine opening to prevent air and water from entering mine.

[d] This seal was located in a subsided area over a haulway. A timber wall was constructed on each side of the subsided area, the area in between filled with sand and capped off with compacted clay.

[e] Three openings that were originally scheduled to have dry seals had highwalls unfavorable for such construction. A compacted backfill was used instead.

[f] Originally two clay seals were constructed; however, one failed and was replaced with a wet seal.

Following reclamation, all disturbed areas were limed, fertilized (1,000 pounds per acre of 10-10-10), and planted with grasses and legumes. On steep areas, trees were also planted.

The work performed in the various work areas of this watershed is described below.

Work Area 1 - Flatbush No. 1 Strip (18.7)--
Because the highwall was sound, a swallowtail backfill was used. The drainage channel discharged over the outslope on the southeast corner. A gully formed in the outslope at the discharge point. For future work it is recommended that a control structure such as a chute spillway, drop inlet, or drop spillway be constructed to carry the water over the outslope. Other than this gully, results of the backfilling grading were good.

Agricultural limestone (2.8 tons per acre) and 10-10-10 fertilizer (0.64 ton per acre) were applied by truck. On the 10 acres of bench the following grasses and legumes were planted in April 1968: rye grass (RVP Malli rye grass from Belgium) - 5 lb/acre, Sericea lespedeza - 15 lb/acre, tall fescue - 10 lb/acre, tall oat grass - 10 lb/acre and Charlottetown 80 barley - 5 lb/acre. A grab mixture of scotch, shortleaf, Virginia, and white pine was hand-planted on the 8.7 acres of outslope in March 1968 at a rate of 827 trees per acre. The outslope was also hydroseeded in May 1968 with the same mixture of grasses and legumes as used on the bench. The fertilizer and seed were hydroseeded with Metroganic 100 mulch (1 ton per acre).

During the first growing season the growth of grasses and legumes was slow. Rye grass and fescue were present over most of the area, but lacked vigor. S. lespedeza was hardly detectable. Some oat grass and barley were present, but provided little cover. By 1970, the rye grass and fescue on the bench had essentially stabilized the area. S. lespedeza was becoming more prevalent. The outslope had far less vegetation, especially on the southeast side where very little growth was present. Few of the pines survived.

In 1971, the S. lespedeza had taken control of the western half of the area and was beginning to take over the eastern end.

By 1976, the bench and western end of the area was stabilized. The only unstable area was a small part of the steep outslope on the eastern end.

Work Area 2 - Flatbush No. 1 Strip Continued (40.3 acres)--
The western 25 percent of the area was pasture backfilled and the eastern portion was swallowtail backfilled. The drainage channel for the swallowtail had inadequate facilities for discharge over the outslope. In addition, on the lower end the

channel was too steep and has cut into the backfill. Better channel design was recommended. In this area a section of the pit was to be left open for a deep mine, as a term of the leasing agreement. Before the project was completed, however, permission was given to backfill the whole area. This delay resulted in inefficient use of equipment and extra cost.

Two underground mine openings were sealed in the east end of Work Area 2. Both seals were solid masonry walls, about 6 foot 2 inches high, intended to prevent air and water from entering the underground mine. One was 10 feet wide and the other 14 feet. No outside excavation was necessary, but four cubic yards of excavation was needed inside the mine to set timbers. Three sets of timbers were set inly and outly of the block wall. The wall was set on a concrete footer and coated with bitumastic. Clay was compacted in front of the openings before the area was backfilled.

The bench (35.8 acres) and the outslope (4.5 acres) were planted with the same grasses and legumes used in Work Area 1. Agricultural lime was applied to both at a rate of 2.5 tons per acre. The bench received 1,000 lbs of 10-10-10 fertilizer per acre in April 1968 and was planted in May. The outslope was planted in June. Black alder and Japanese larch were hand-planted at 600 trees per acre. The outslope was hydroseeded with fertilizer, grass seeds, black locust tree seeds (six lbs/acre) and 1,000 lbs per acre of Metroganic 100 mulch.

Vegetative growth was poor on the western half of the area at first. In the spring of 1969, this area was reseeded with black locust, which did not grow. The area remained relatively bare until 1971, when a good growth of _Sericea lespedeza_ developed on the bench.

An evaluation of the area in 1973 found that there was a 60 percent survival of trees with the average height of larch being 7 feet, and alder 8 feet. Grasses and legumes covered 95 percent of the area and only two bare spots were greater than one half acre.

A May 1976 evaluation reported that larch, locust and alder were the primary trees. The hydroseeded locust and alder were 4 to 12 feet tall and some bare spots were present. The black alder stand was poor and many trees were in bad condition. Of the herbaceous species planted, only tall fescue and _S. lespedeza_ persist.

Work Area 3 - Flatbush No. 1 Strip Continued (9.5 acres)--

A contour-type backfill was used at the head of the hollow to carry the small intermittent stream over the highwall. The remainder of the area was graded to a contour and swallowtail backfill. The stream channel formed a small gully that quickly stabilized.

The area was limed in October 1967 at a rate of 3 tons per acre. Grass was drilled in April 1968, and the stream channel hydroseeded in May. The seed mixture was the same used in Work Area 1.

A satisfactory growth of grasses developed the first year. By 1973, 85 percent of the area was covered with grasses and legumes. The area is considered to be satisfactorly stabilized.

Work Area 4 - Prospect Strip (4.7 acres)--

This small area was pasture backfilled. Agricultural limestone was applied by truck (four tons per acre) in October 1967. In April 1968, weeping love grass (7 lb/acre), orchard grass (7 lb/acre), and birdsfoot trefoil (15 lb/acre) were drilled. A very dense growth of orchard grass developed the first year. The love grass could not compete and never made a showing. By 1970, a good stand of trefoil had also developed. In 1973 the grasses and legumes covered 90 percent of the area. The area is now considered to be completely stablized.

Work Area 5 - Flatbush No. 1 Strip Continued (4.3 acres)--

A stable highwall was present in this area and pasture backfilling was performed. Lime was applied in October 1967, and the area was planted in April 1968. As with all the vegetated areas, 10-10-10 fertilizer was applied at 1,000 pounds per acre. The seed mixture was the same as used in Work Area 1. A good growth of rye grass and fescue developed the first year. By 1971, a vigorous growth of S. lespedeza was present. By 1973 ground cover was 85 percent. The area can be considered stabilized (see Figure A-5 and A-6).

Work Area 6 - Flatbush No. 1 Strip Continued (12 acres)--

A pasture backfill was constructed to drain the water away from the highwall and the adjacent underground mine. Clay was compacted into two of the underground mine openings to form a seal. The regraded area was limed with 2 tons per acre in October 1967. In April, the area was fertilized and planted with weeping love grass (10 lb/acre), orchard grass (3 lb/acre), Kentucky bluegrass (10 lb/acre), birdsfoot trefoil (10 lb/acre), and alsike clover (2 lb/acre). The drainageway through the area was hydroseeded with the same mixture. An excellent growth of orchard grass, clover, and trefoil developed. Although some erosion developed in the drainage way, it was not excessive. By 1973 ground cover was 90 percent. The area can be considered stabilized.

Work Area 7 - Flatbush No. 1 Strip Continued (17 acres)--

Three solid masonry seals were constructed in portals that were once the Sainato mine. Two of the seals were within the

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Figure A-5. Work Areas 5 and 6 in fall of 1968.

Figure A-6. Work Areas 5 and 6 in summer of 1976.

same opening. Approximately 163 cubic yards of excavation was required outside the portal, and an additional 70 cubic yards for one seal and 42 cubic yards for the other to gain access to a suitable site for the seal, make the area safe for workmen, and prepare the site. Three to four sets of timbers were set inly and outly of the seal to keep the roof load off it and to provide a safe working area. The seals were 12.5 feet wide by 7 feet high and 15 feet wide by 7.5 feet high. A concrete footer was poured and the wall was made of solid concrete blocks. The seal was faced and tied to the walls and roof with urethane foam.

The third masonry seal required no outside excavation and only 12 cubic yards on the inside. It was constructed in the same manner as the other two seals.

A fourth opening was sealed with 64 cubic yards of compacted clay.

Because of the poor condition of the highwall a contour backfill was used to cover the four mine seals. The area received the same soil amendments and grass-legume planting used in Work Area 6. An excellent growth of grass and legumes was established and in 1973 a 90 percent vegetative cover was present.

A 1976 survey revealed that orchard grass was doing well and was growing in clumps. There was also a lot of St. John's Wart volunteering into the area.

Work Area 8 - Flatbush No. 1 Strip Continued (5.6 acres)--
Part of this area is in Flatbush Fork watershed and is considered later in Appendix A. The openings at F and G were compacted with clay to prevent water from entering the underground mine. The area was then pasture backfilled. It received the same soil amendments and grass-legume planting used in Work Area 6. An excellent growth of grass and legumes was established, and in 1973 90 percent of the area had vegetative cover. The 1976 survey found orchard grass and Kentucky bluegrass dominating.

Cost of Work

Records were kept of equipment and labor used in each work area. These data were used to determine the direct cost as reported in Table A-12. The remaining costs were then distributed on a direct-cost percentage basis to the work area. For the cleaning and grubbing, reclamation, and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total costs for each work area are reported in Table A-13.

TABLE A-12. COST OF WORK - DIRECT COST (DOLLARS)[a]

Area No.	Cleaning and grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment and materials	Labor	
1	324	45	4,750	1,142	78	15	3.760	564	10,683
2	283	815	22,955	6,263	956	307	3,828	562	35,969
3	41	454	3,465	1,100	0	424	1,530	264	7,278
4	81	77	220	45	0	0	365	30	818
5	0	47	3,614	665	0	0	471	94	4,891
6	83	91	31,915	5.560	701	2,530	736	176	41,792
7	143	880	29,098	4,486	306	887	1,187	163	37,150
8	1,067	473	4,207	1,646	1,732	3,275	633	154	13,187
23-24	701	2,179	28,200	2,824	1,793	1,279	15,279	3,643	55,671

[a] For cleaning and grubbing, reclamation and underground work. This includes only the actual cost of equipment and labor and does not include any materials, overhead, G&A, etc. Revegetation cost includes actual cost of labor, equipment and material.

TABLE A-13. TOTAL COST FOR WORK AREAS IN NORTH BRANCH FLATBUSH FORK

Area No.	Cleaning and grubbing, reclamation, underground	Vegetation	Total	Cost/acre
1	8,246	5,410	13,656	730
2	40,982	5,387	36,369	1,151
3	7,117	2,200	9,317	783
4	549	483	1,032	220
5	5,614	694	6,308	1,467
6	53,052	1,143	54,195	4,516
7	46,460	1,674	48,134	2,831
8	16,092	962	17,054	2,159
23-24	47,986	22,822	70,808	909

Costs per acre were lowest in areas where extensive mine sealing, grading, and hydroseeding were not performed. Highest costs were in Work Area 6, which required two seals, and considerable earth moving because of toxic material.

Results of Reclamation

As shown in Table A-8, the total pollution load has been reduced during the postreclamation years. Considering 1966 as the prereclamation base year, acidity, total iron, and sulfate loads have been reduced by 58 percent, 54 percent, and 47 percent through 1970. Extremely heavy rains in September 1971 caused unusually high runoff values and therefore produced the high load values for that year. The mineral load decreased as the cover crops developed and reduced the runoff and contact time with deleterious materials. The rainfall was nearly constant for three years after reclamation (Table A-9) and 2 to 3 inches less than in 1967; total runoff rose above the prereclamation value in 1968, and dropped off during 1970. Runoff is a direct indicator of the benefit derived from cover crops. In 1966, the spoil areas were bare. A yearly rainfall of nearly 45 inches produced 0.43 billion gallons of mineral-laden water. In 1968, 41.46 inches of rain produced 0.48 billion gallons of runoff. The newly graded strip mines expedited drainage and less water soaked into acid-forming deposits and underground mines. As the cover developed in 1969 and 1970, with equal yearly rains, more and more surface water was trapped in the topsoil and used by the plants. The 8.14 inches of rain in September 1971 produced heavy overland flow and rapid flooding which is indicated in the 0.52 billion gallons of runoff produced for that year. Chemical analysis showed lower concentrations of pollutants (see Table A-9), indicating less contact with deleterious material. The vegetation seals the surface against air and overland flow, and then absorbs and uses much of the surface water.

The small underground mine in Work Area 24 (RT 9-11) was sealed in 1967 to restrict the inward flow of oxygen. The air seal impounded about 2 feet of water in the mine. As shown in Table A-14, the oxygen content within the mine had been reduced but not eliminated. During the latter months of 1969, the oxygen content increased markedly. No explanation has been found for this happening. A marked reduction in acid and sulfate concentration occurred shortly after the mine was sealed, even before the oxygen concentration was reduced. This reduction is believed to be due to a change in the hydraulics of the mine, since 2 feet of water were ponded in it as a result of the seal, and not to a reduction in acid formation. The quality of the water has been fairly constant since the initial decrease and appears to have reached equilibrium.

FLATBUSH FORK WATERSHED (RT 9-23)

Area Description

The Flatbush Fork watershed encompasses 3,397 acres of land on the western side of the Roaring Creek watershed (Figure A-7). It is a large oblong area 3.7 miles long and 1.5 miles wide. The southernmost branch of Flatbush Fork has its headwaters 5 miles upstream from the mouth. Forming at an elevation of 2,650 feet, the channel drops at an average rate of 0.016 ft/ft to its mouth at 2,255 feet. The southern end of the watershed contains the most relief, with ridges rising to 3,857 feet. The northern sector is described more completely earlier in Appendix A (see North Branch Flatbush Fork segment).

Mining Summary and Work Area Description

Strip mining has disturbed 192 acres or roughly 6 percent of the watershed. One hundred thirty one acres lie in the North Branch watershed as presented earlier. Areas not previously considered are 14 acres in Work Areas 8 and 9, 14 acres in Work Area 23, 12.6 acres in Work Area 27, and 20.1 acres in Work Areas 25 and 26. The acreage in Work Areas 25 and 26 was not reclaimed, except for trees planted in Work Area 26.

As noted earlier the large underground mine is adjacent to Work Areas 3 - 9. Water drained through the strip areas into the underground mine and eventually was discharged at mine openings RT 6-23, RT 6-9, and GT 6-1. A portion of the large underground mine also adjoined Work Area 27. Because of localized dips, part of the underground drainage seeps through the strip mine in Work Areas 27G and 27 H-J (see Figure A-7). Most of the drainage is either to the northeast and Station RT 6-12

TABLE A-14. EFFECTIVENESS OF MINE SEAL RT 9-11

Before sealing[a]	Oxygen, percent	Acidity, mg/l	pH[b]	Iron, mg/l	Sulfate, mg/l
Mean	21	591	2.8	93	1,035
Minimum	-	438	3.1[c]	48	710

After sealing

	Oxygen, percent				pH value			
Quarter	1	2	3	4	1	2	3	4
Year								
1967	-	-	-	9.1	-	-	-	3.2
1968	8.3	10.8	7.0	7.4	3.2	3.2	3.2	3.2
1969	-	-	7.0	14.8	3.2	3.2	3.2	3.2
1970	15.0	12.0	-	13.3	3.1	2.9	3.1	3.3
1971	15.0	15.3	14.0	-	3.2	3.2	3.0	2.9

	Acidity, mg/l				Iron, mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1967	-	-	-	359	-	-	-	85
1968	325	334	344	265	74	68	72	72
1969	350	339	376	327	63	91	62	71
1970	263	310	297	294	74	49	72	83
1971	249	248	276	326	56	47	56	73

	Sulfate, mg/l			
Quarter	1	2	3	4
Year				
1967	-	-	-	797
1968	686	702	708	627
1969	645	656	717	678
1970	603	628	845	606
1971	488	508	406	535

[a] March 1964 - August 1967.

[b] Median value.

[c] Maximum value.

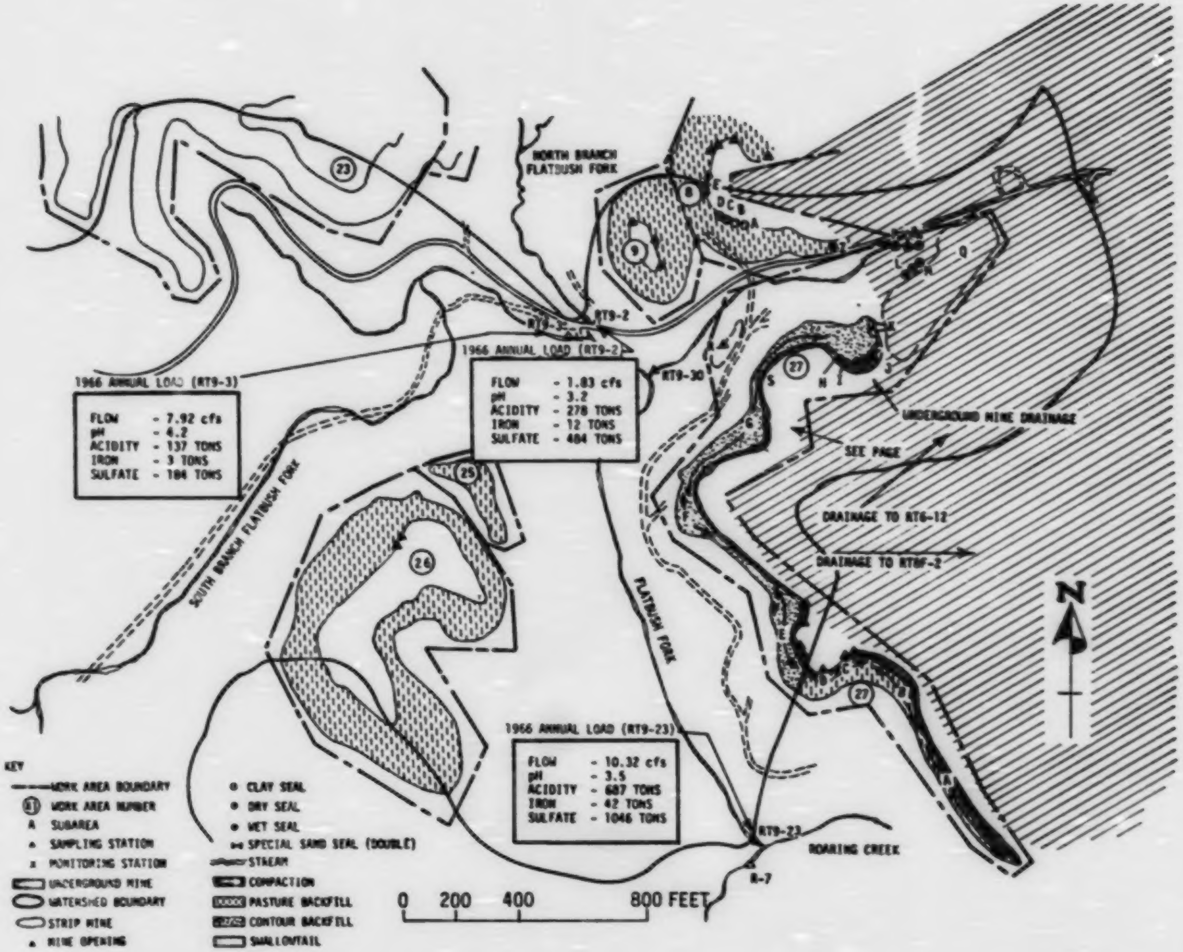
23
NORTH BRANCH FLATBUSH FORK
8
F
D C B
A
9
RT9-2
RT9-3
1966 ANNUAL LOAD (RT9-3)
FLOW - 7.92 cfs
pH - 4.2
ACIDITY - 137 TONS
IRON - 3 TONS
SULFATE - 184 TONS
1966 ANNUAL LOAD (RT9-2)
FLOW - 1.83 cfs
pH - 3.2
ACIDITY - 278 TONS
IRON - 12 TONS
SULFATE - 484 TONS
RT9-30
27
S
H
UNDERGROUND MINE DRAINAGE
SEE PAGE
DRAINAGE TO RT6-12
DRAINAGE TO RT8F-2
25
26
SOUTH BRANCH FLATBUSH FORK
FLATBUSH FORK
N
1966 ANNUAL LOAD (RT9-23)
FLOW - 10.32 cfs
pH - 3.5
ACIDITY - 687 TONS
IRON - 42 TONS
SULFATE - 1046 TONS
RT9-23
ROARING CREEK
R-7
27
A
KEY
WORK AREA BOUNDARY
WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
STRIP MINE
MINE OPENING
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STREAM
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 200 400 800 FEET

Figure A-7. Flatbush Fork watershed (RT9-23).

(Work Area 17) or to the east and Station RT 8F-2 (Work Area 30).

The work areas and corresponding subareas within this watershed are shown in Figure A-7 and described below.

Work Area 25 - Lower Flatbush Fork Strip (2.5 acres)--
This was an unbackfilled prospect strip, which appeared to be causing very few problems.

Work Area 26 - Upper Flatbush Fork Strip (17.6 acres)--
Little or no regrading was done. The area did not appear to be creating a major problem.

Subarea A--This was a 16-foot opening in the highwall driven 15 feet into solid coal.

Subarea B--This was a 16-foot opening in the highwall caved 40 feet back, and had slight discharge (less than 1 gpm), pH - 2.9, acidity - 172 mg/l, and iron - 19 mg/l (RT 6-29).

Work Area 27 - Travise Strip (12.6 acres)--
Strip area 27A-D did not drain to Flatbush Fork, but to Roaring Creek and is therefore described later in the Appendix. (See the Middle Roaring Creek segment presented later in Appendix A).

Subarea E--Leveled backfill planted in white pine and locust. Drainage was toward the highwall, along which were four concealed openings.

Subarea F--Eight concealed openings were located in this unbackfilled strip.

Subarea G--No openings were apparent along the highwall, but there was extensive subsidence behind it.

Subarea H--A 12-foot by 7 1/2-foot opening to the mine in fair condition with discharge (RT 9-17) less than 0.2 cfs, pH - 2.5, acidity - 1,345 mg/l, and iron - 278 mg/l.

Subarea I--A 12-foot by 7 1/2-foot opening in fair condition yielding no discharge.

Subarea J--Concealed opening.

Subarea K--Three concealed openings with no noticable drainage.

Subarea L--Partially concealed opening draining only during wet weather.

Subarea M--Partly concealed dry opening.

Subarea N--Dry mine opening in fair condition.

Subarea O--Opening to the underground mine was dry and in fair condition.

Subarea P--Large mine opening caved at 40 feet. Drainage (RT 9-5) less than 0.5 cfs, pH - 3.2, acidity - 215 mg/l, and iron - 35 mg/l.

Subarea Q--Area of extreme subsidence.

Subarea R--A 150-foot prospect strip being used as a garbage dump. A slight discharge (RT 9-20) of 0.02 cfs or less, pH - 3.6, acidity - 400 mg/l, and iron - 150 mg/l.

Work Area 8 - Flatbush No. 1 Strip Continued (2.3 acres)--
Part of Work Area 8 is in the North Fork Flatbush Run watershed (described earlier in Appendix A).

Subarea A--A 14-foot mine opening with no drainage.

Subarea B--A 16-foot mine entry with no drainage.

Subarea C--A 14-foot fan portal with no drainage.

Subarea D--A 14-foot haulage portal in good condition.

Subarea E--Concealed opening in the highwall.

Work Area 9 - Strip mine (11.7 acres)--
A strip in the Kittanning seam encircling a small knoll. The area had not been backfilled, and three dry openings were present in the highwall.

Work Area 23 - Upper Pumpkintown Road Strip (14 acres)--
The Upper Pumpkintown Road Strip was considered earlier (see North Branch Flatbush Fork segment of Appendix A).

Description of Mine Drainage Problem

The flow from Flatbush Fork, measured at Station RT 9-23, constitutes a large portion of the total flow of Roaring Creek, accounting for nearly a fourth (23 percent) of the water passing the mouth of Roaring Creek in 1966 (Tables A-15 and A-16).

TABLE A-15. SUMMARY OF ANNUAL DATA FOR STATION RT 9-23, MOUTH OF FLATBUSH FORK

Year	Rain, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Before reclamation					
1965	37.77	1.88	537	38	974
1966	47.14	2.43	687	42	1,046
After reclamation					
1968	55.88	2.94	504	35	947
1969	41.46	1.93	433	31	648
1970	42.58	2.49	456	45	864
1971[a]	16.43	2.14	247	33	199

[a] Data for first one-half year only.

During the base year 1966, Flatbush Fork carried 687 tons of acidity, 42 tons of iron, and 1,046 tons of sulfate. These amounts represent 19 percent, 16 percent, and 20 percent of the corresponding loads carried by Roaring Creek.

The most polluted areas of the watershed were the North Branch and the unnamed tributary measured by Station RT 9-30 (Figure A-7 and Table A-17). The North Branch is polluted almost entirely by surface mine runoff (discussed earlier in Appendix A); RT 9-30 receives water from both underground drainage and surface mine runoff. Since RT 9-30 was not sampled after 1967, the contribution to the lower mainstream, between the confluence of the North and South Branches and the mouth, was assumed to be the difference between the values at Stations RT 9-2 and RT 9-3, and the values at the mouth, Station RT 9-23. This analytical procedure appears reasonable because for 1966, when RT 9-30 was measured, the acidity and sulfate loads were 312 and 326 tons, respectively, as compared to 272 and 378 tons respectively, as determined by the "difference method."

Reclamation Work Performed

Except for Work Areas 25 and 26, all of the disturbed lands in this watershed were reclaimed. Work Area 26 was planted with trees, but no other reclamation took place. For bidding purposes, Work Areas 27, 29, and 30 were combined. The excavation estimated in the contract (Table A-18) was 492,000 cubic yards. A survey following reclamation revealed that 554,127 cubic yards

TABLE A-16. SUMMARY OF QUARTERLY DATA FOR STATION RT 9-23, MOUTH OF FLATBUSH FORK

Quarter Year	Flow in cfs				pH value			
	1	2	3	4	1	2	3	4
1965	21.27	9.36	0.24	0.99	3.6	3.3	3.1	3.3
1966	14.32	15.07	1.18	10.73	3.6	3.5	3.2	3.5
1967	24.70	17.57	2.36	9.04	3.5	3.6	3.6	4.0
1968	12.23	21.47	0.79	15.35	4.0	4.1	3.4	3.8
1969	9.25	5.82	8.99	8.62	4.1	3.8	3.3	3.7
1970	18.77	8.03	2.75	12.68	4.0	3.6	3.6	4.1
1971	30.23	6.00	-	-	4.3	3.9	-	-

Quarter Year	Specific conductance in μmhos/cm			
1965	291	417	735	624
1966	264	310	662	289
1967	271	263	324	173
1968	476	148	615	331
1969	231	336	321	260
1970	380	290	381	145
1971	118	196	-	-

Quarter Year	Acidity							
	Load in tons				Concentration in mg/l			
1965	283	202	11	41	54	88	193	171
1966	227	256	45	159	65	69	155	60
1967	307	137	40	74	51	32	69	33
1968	130	145	44	185	43	28	230	49
1969	100	102	132	99	44	72	60	47
1970	150	140	46	120	33	71	68	39
1971	190	57	-	-	26	39	-	-

Quarter Year	Iron							
	Load in tons				Concentration in mg/l			
1965	22	14	5	1	4	6	9	5
1966	15	17	2	8	4	5	6	3
1967	33	17	2	12	5	4	3	6
1968	11	5	2	17	4	1	11	5
1969	7	8	8	8	3	6	4	4
1970	21	9	3	12	5	5	5	4
1971	29	4	-	-	4	3	-	-

(continued)

TABLE A-16 (continued).

Quarter Year	Sulfate							
	Load in tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
1965	541	350	19	64	104	152	321	265
1966	330	372	77	267	94	101	264	101
1967	533	366	78	326	88	85	134	147
1968	174	219	63	491	58	42	327	131
1969	164	130	266	128	73	91	103	61
1970	312	174	153	225	68	88	227	73
1971	132	67	-	-	18	46	-	-
	Hardness							
	Load in tons				Concentration in mg/l			
1965	265	179	10	47	50	77	177	152
1966	139	180	42	156	39	48	146	59
1967	290	172	54	92	47	39	93	41
1968	117	149	27	371	38	28	141	98
1969	121	121	323	106	53	85	146	50
1970	201	53	46	99	43	27	68	32
1971	293	42	-	-	40	29	-	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	120	6	22	-	52	101	90
1966	80	101	21	82	23	27	74	31
1967	153	89	28	57	25	21	48	26
1968	68	91	17	204	23	17	86	54
1969	76	73	261	63	34	52	119	30
1970	120	57	35	94	26	29	51	31
1971	147	32	-	-	20	22	-	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	25	1	4	-	11	18	16
1966	14	18	4	12	4	5	13	5
1967	22	17	3	8	4	4	5	4
1968	29	6	4	33	10	1	22	9
1969	12	9	25	10	5	6	11	5
1970	26	6	4	11	6	3	5	4
1971	22	4	-	-	3	3	-	-

TABLE A-17. AREAS OF POLLUTION CONTRIBUTION FOR FLATBUSH FORK WATERSHED

	1966		1968		1969		1970		1971	
	Acidity tons	Sulfate tons	Acidity tons	Sulfate tons	Acidity tons	Sulfate tons	Acidity tons	Sulfate tons	Acidity tons	Sulfate tons
Flatbush Fork RT 9-23	687	1,046	504	947	433	648	456	864	247[a]	199[a]
North Branch RT 9-2	278	484	151	435	143	307	117	255	-	-
South Branch RT 9-3	137	184	100	222	63	200	42	116	-	-
Lower Mainstream RT 9-30	272	378	253	290	227	141	297	493	-	-

[a] Difference between Flatbush Fork and sum of North and South Branch.

were moved. A large percentage of the extra yardage was due to reclamation above the highwall to correct subsidence. This area had not been included in the original estimates.

TABLE A-18. EXCAVATION - FLATBUSH FORK

	Areas 25 - 26	Areas 27, 28, & 30
Common excavation, cu. yd		
Contract estimate	83,000	292,000
Actually completed	0	380,000
Difference	- 83,000	+ 83,393
Subsidence excavation, cu. yd.		
Contract estimate	0	83,000
Actually completed	0	162,456
Difference	0	+ 79,456
Compacted backfill, cu. yd.		
Contract estimate	0	34,000
Actually completed	0	11,671
Difference	0	- 22,329
Total		
Contract estimate	83,000	409,000
Actually complete	0	554,127
Difference	- 83,000	+145,127

Work Area 8 - Flatbush No. 1 Strip Continued (2.3 acres)--

Part of this area was in the North Branch watershed. Clay seals were constructed at Subareas A, B, C, and D to prevent water from entering the underground mine. Seals A, B, and C, each required 92.6 cubic yards of outside excavation; seal D required 433 cubic yards of outside excavation and 87 cubic yards of inside excavation. At Subarea 8H, a subsidence hole developed next to the roadway. This hole allowed surface waters direct access to the underground mine. As part of the modified construction plan the area was sealed by constructing timber walls across the haulway on each side of the subsidence area, filling the space between with sand and then capping the hole with compacted clay. The refuse pile near Subarea A was buried in the backfilling operation. A compacted backfill was used next to the highwall throughout Work Area 8. The final grading was to pasture backfill.

The area was revegetated by applying 2 tons/acre of agricultural limestone in October 1967. This application was followed by the addition of 1,000 lb/acre of 10-10-10 fertilizer, 10 lb/acre of love grass, 3 lb/acre of orchard grass, 10 lb/acre of Kentucky bluegrass, 10 lb/acre of birdsfoot trefoil, and 2 lb/acre of alsike clover in May 1968. Love grass was predominant for the first 2 years. By 1971, birdsfoot trefoil and orchard grass had taken over the area, with a good stand also of alsike clover. The grass growth in this area is excellent, with over 90 percent cover in 1973. By 1976 orchard grass was still the predominant grass; however large amounts of Kentucky bluegrass were also present.

Work Area 9 - Strip Mine (11.7 acres)--

This area was pasture backfilled. The procedures used in revegetation were the same as for Work Area 8, except that bluegrass was not included. Orchard grass was more successful in the area than love grass because of the more favorable soil pH. A good cover developed the first season and has been maintained with an estimated 100 percent cover, both in 1973 and 1976.

Work Area 25 - Lower Flatbush Fork Strip (2.5 acres)--

No reclamation took place in this area. By 1972, a good stand of voluntary trees had developed.

Work Area 26 - Upper Flatbush Fork Strip (17.6 acres)--

Clearing and grubbing had just begun in this area when the project was terminated. No reclamation was done in this area except the planting of trees in May 1968. Trees were planted in a six-row band of European black alder, followed by a six-row band of a grab mixture of Japanese larch, tulip poplar, cottonwood, and white oak. By the fall of 1971, approximately 80 percent of the trees were surviving. Almost 100 percent of the alder had survived and were about 4 feet tall. Good stands of oak and larch about 2 feet tall were also present. Although the stand of trees is excellent, the ground is still relatively bare and some erosion is taking place.

Work Area 27 - Travise Strip (12.6 acres)--

All of the mine sealing was in the vicinity of Work Area 27 H-P. Construction of two clay seals at Work Area 27K required 172 cubic yards of excavation. The third opening was tightly caved and no additional work beyond normal backfilling was performed.

At Work Area 27J, four openings were discovered as the highwall was cleaned. In each of these openings a dry seal was constructed by timbering the opening and constructing a solid masonry block wall coated with urethane foam. Construction of these seals required 566 cubic yards of inside excavation. Since the localized dip of the coal resulted in water draining through these openings during wet periods, some head would develop behind these seals. The seals were covered during the normal backfilling operation.

Construction of dry seals at Work Areas 27H and I, similar to those in Work Area 27J, required 167 cubic yards of outside excavation and 67 yards of inside excavation.

At Work Areas 27 N, O, and P, dry seals were constructed, similar to those in Work Area 27J, but installed to prevent water from entering the underground mine. Only 24 cubic yards of outside excavation and 77 of inside excavation were required. Two other openings in the area were plugged during the excavation, backfilling, and compaction of Work Area 27Q.

Dry seals were constructed in three openings at Work Areas 27 L-M. Excavation required 513 and 123 cubic yards for outside and inside work respectively.

Throughout Work Area 27 E-K, clay was compacted against the highwall to prevent water from entering or seeping from the underground mine. The entire area was contour backfilled. Work Area 27Q was regraded to a contour backfill to correct subsidence.

After regrading, two problems became apparent in Work Area 27 G-K. First, the long (600-foot) steep slopes were conducive to erosion which could have been reduced by cutting of a diversion ditch at the top of the slope and building of several terraces. A road cut across the slope in 1968 to facilitate hydroseeding helped control the erosion. Secondly a large seepage area developed in early 1968 below Work Area 27 H-K. The seals and/or compacted backfill do not hold water in the underground mine. The seepage area covers about 5 acres that support no vegetation. This underground mine seepage is a major contributor to the pollution of Flatbush Fork (see Table A-17).

One small subsidence hole developed in Work Area 27Q after reclamation, requiring less than $100 to repair. Since Work Area 27Q was initially a subsidence area, development of only one additional subsidence hole in 5 years indicates potential for stability.

Revegetation of Work Area 27 called for planting of grass and legumes on all of the disturbed land. In the more level areas at the bottom of the slopes, conventional planting techniques were used. The steeper slopes were hydroseeded with grass seed, 1,000 lb/acre of mulch and 1,000 lb/acre of 10-10-10 fertilizer; then trees were planted. Agricultural limestone in amounts ranging from 2 to 3.5 tons per acre was applied in March and April 1968. The grasses and legumes (love grass - 10 lb/acre, birdsfoot trefoil - 15 lb/acre, and tall fescue - 15 lb/acre) were conventionally planted in April 1968 and hydroseeded in May 1968. The trees (six rows of European black alder then six rows of a grab mixture of scotch, Virginia, shortleaf, and white pine) were planted in March and April 1968.

Except for the 5-acre seepage area in Work Area 27 H-J, a small seepage area (less than 1 acre) in 27G, and a very toxic 1 acre in 27G, a dense growth of grasses and legumes has developed. During the first year, love grass was very prevalent; by 1972, tall fescue and trefoil had taken over. The alder had more than 80 percent survival and stood 6 to 10 feet tall in 1972. In spite of the dense grass growth that engulfed the pine trees, their survival rate was 60 percent or more.

Competition of the grass has slowed the growth of the pines, however, and they were only 2 to 5 feet tall in 1972.

A 1973 evaluation found there to be a 95 percent ground cover and the alder to be 12 to 16 feet tall and the pine 3 to 5 feet. The 1975 evaluation reported the pines to have good survival and the average height was 8 to 10 feet. Black alder had degenerated to about 25 percent stand and many trees were dying from fungus infection. Tall fescue was dominant at about 90 percent stand. Very little birdsfoot remains and there was no weeping love grass.

Although the strip mine and subsidence areas can be considered stabilized, the deep mine seepage is a major pollution problem (Figure A-8).

Cost of Work

Records of equipment and labor used in each work area were used to determine the direct cost as reported in Table A-19. The remaining costs were then distributed to the work areas on a direct-cost percentage basis. For the cleaning and grubbing, reclamation, and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total costs for each work area are reported in Table A-20.

The low cost for Work Area 9 is a result of ease of grading and revegetation. The only cost incurred at Work Area 26 was for planting trees. Costs in Work Area 27 were higher because of building seals and grading contour backfills.

Results of Reclamation

The flow of Flatbush Fork has not changed appreciably since 1966, except for effects introduced by seasonal variations in rainfall. The acid and sulfate loads have been much lower, dropping from 687 tons of acidity and 1,046 tons of sulfate in

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Figure A-8. North end of Work Area 27, summer 1976.

TABLE A-19. COST OF WORK - DIRECT COSTS (DOLLARS)[a]

Area No.	Cleaning and grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment & Materials	Labor	
9	-	425	3,877	1,185	-	-	888	171	6,546
26	62	54	-	-	-	-	212	861	1,189
27	10,170	15,371	31,973	4,792	5,225	9,897	20,638	4,323	102,299

[a] For cleaning and grubbing, reclamation and underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G&A, etc. Revegetation cost includes cost of labor, equipment and materials.

TABLE A-20. TOTAL COST FOR WORK AREAS (DOLLARS)

Area number	Cleaning & grubbing reclamation, underground	Revegetation	Total	Cost per acre
9	7,121	1,299	8,420	720
26	151	1,371	1,522	85
27	100,366	30,776	131,142	1,929

1966, to 456 tons and 864 tons, respectively, in 1970 (Table A-15 and A-16). Data for the first 6 months of 1971 showed that reduced acidity and sulfate were continuing. Most of this gain in water quality results from work performed on the North Branch (discussed earlier). Table A-17 shows that the pollution load from the South Branch has decreased also. A small reduction in the lower mainstream was due to strip mine reclamation but, because of the underground mine seepage in Work Area 27, no great improvement can be expected in that reach.

Surface mine reclamation can be credited with approximately 34 percent decrease in acidity and 47 percent decrease in sulfate in water from this watershed.

MABIE WATERSHED (RT 8F-1)

Area Description

The major portion of this 206-acre watershed lies to the northwest of Mabie, West Virginia. It is more populated than other watersheds nearby, with houses along Route 4 and 17. The basin is 0.6 miles wide by 0.9 miles long, supporting 0.5 miles of stream channel. The tributary, with its mouth on Roaring Creek at elevation 2,221 feet, has an average gradient of 0.011 ft/ft to its headwaters. Hills around the drainage area rise to 2,420 feet.

Mining Summary and Work Area Description

Nineteen percent of the land area, 39 acres, has been disturbed by mining. The drainage problems originate from abandoned strip mines and because of extensive subsidence over the underground complex. In addition, drainage from the deep mine contributes substantially to the total pollution load during dry seasons.

Four work areas are included or partially included in this watershed and they are shown in Figure A-9 and described below.

Work Area 28 - Prospect Strip (7.3 acres)--
Part of this area is in Middle Roaring Creek area (described later in Appendix A, see Middle Roaring Creek segment).

Subarea A--Areas of subsidence. Runoff (RT 8F-4), flow 0 to 0.24 cfs, pH - 2.8, acidity - 245 mg/l, and iron - 22 mg/l.

Work Area 29 - Ray Strip (1.3 acres)--
Subarea A--Twelve or more openings along highwall.

Subarea B--Concealed opening at turn of strip pit.

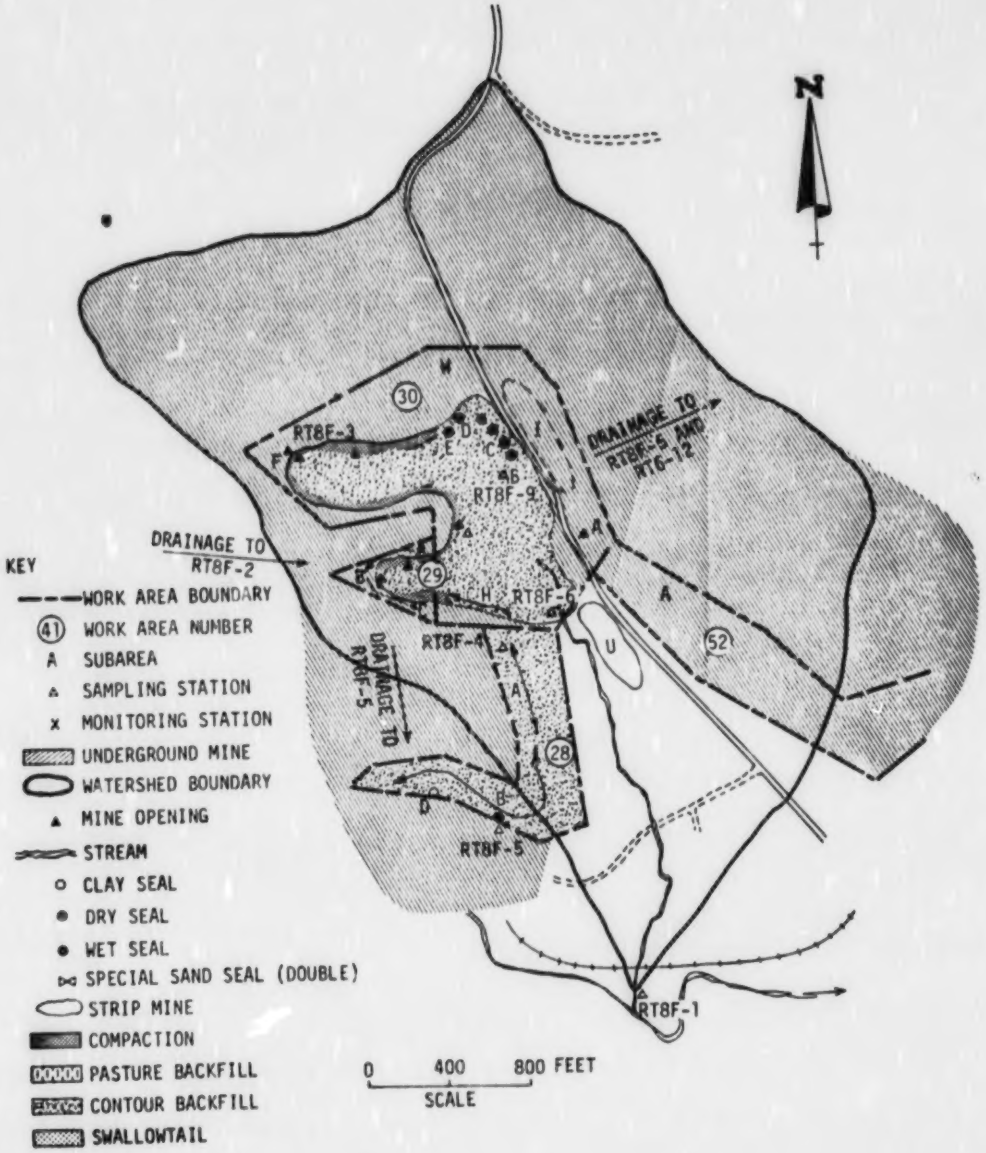
N
30
RT8F-3
F
D
E
C
6
RT8F-9
DRAINAGE TO RT8F-5 AND RT6-12
DRAINAGE TO RT8F-2
29
B
H
RT8F-6
A
U
52
RT8F-4
A
DRAINAGE TO RT8F-5
28
D
B
RT8F-5
RT8F-1
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
x MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 400 800 FEET
SCALE

Figure A-9. Mabie watershed (RT 8F-1).

Subarea C--Considerable subsidence above highwall and a number of concealed openings.

Work Area 30 - Ray Strip Continued (19.7 acres)--

Subarea A--Caved mine portal, 14 feet wide. No gravity discharge was apparent, but seepage was evident 100 feet to the west.

Subarea B--Ralph Ray mine portal showed no evidence of discharge.

Subarea C--A 12-foot opening in the highwall to Ray Mine. This was the drainage portal (RT 8F-9). Flow - 0 to 0.67 cfs, pH - 2.7, acidity - 525 mg/l, and iron - 100 mg/l.

Subarea D--Old fan opening in the highwall. No drainage was evident but 2 feet of water was impounded on the floor.

Subarea E--A 3-foot dry opening to the old workings.

Subarea F--The coal had been completely stripped in this swale. The highwall had sloughed down, and excessive subsidence indicated that the old mine workings were intercepted.

Subarea G--Twenty-six or more openings in the highwall. Discharge (RT 8F-2) had flow 0 - 0.22 cfs, pH - 2.6, acidity - 766 mg/l, and iron - 106 mg/l.

Subarea H--Subsidence close to the highwall.

Subarea I--Subsidence area near the Coalton-Mabie road.

Work Area 52--

Area undermined by Brady Mine with no apparent openings. A small active exploratory strip.

Description of Mine Drainage Problem

Though small, this watershed has a complex mine drainage problem. In addition to the surface and underground mines, it includes large areas of subsidence. During the base year 1966, underground discharge RT 8F-2 contributed 32 tons of acidity and 36 tons of sulfate, or 62 percent and 48 percent respectively of these constitutents at the mouth of RT 8F-1 (Table A-21). The flow at this sampling station was very low.

Reclamation Work Performed

Excavation work for Work Areas 28-30 was combined with Work Area 27 in the contract. Information pertaining to Work Area 27

TABLE A-21. SUMMARY OF ANNUAL DATA FOR STATION RT 8F-1, MOUTH OF SMALL TRIBUTARY, AND RT 8F-2, UNDERGROUND DISCHARGE

Year	Rain, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Before reclamation					
1966	46.6	.046	48	6.5	63
After reclamation					
1968	45.1	.043	13.1	2.4	27.1
1969	58.7	.063	44.5	4.8	69
1970	53.9	.014	5.8	0.6	8
1971	49.2	.029	11.3	2.5	13.4
Before reclamation					
1965		.008	4	0.5	5
1966		.059	32	4.5	36
After reclamation					
1968		.048	23	3.1	29
1969		.029	15	2.2	18
1970		.014	4.3	0.5	7
1971					

was discussed earlier in Appendix A (see the Flatbush Fork watershed segment).

Work Area 28 - Prospect Strip (7.3 acres)--
Two seals were constructed in Work Area 28, but they are not in this watershed and will be considered later. Correction of subsidence in Work Area 28A involved more than twice the area originally estimated. The area was finally graded to contour backfill.

Work Areas 29 and 30 - Ray Strip (20 acres)--
During construction, Work Areas 29 and 30 were blended. At underground mine discharge RT 8F-2, a drain was constructed instead of a seal. A wet seal at this location was not considered advisable because water backing up in the mine might wash out the backfill. A conduit of creosoted lumber was constructed to carry the water through the backfill. The conduit was 98 feet long, 6 feet wide, and 6 inches high.

Six dry seals were constructed in Work Area 30 B-E. The purpose of these seals was to prevent water from entering the deep mine. Each opening was timbered and closed by a solid block wall coated with urethane. These seals required 208 cubic yards of excavation on the outside and 93 on the inside. They were covered with a contour backfill.

An extremely large subsidence area not covered in the original estimates was found during construction in Work Area 30W. A borrow area (30U) was developed to provide fill material for Work Area 30W. A total of 18,400 cubic yards was moved from 30U to 30W.

Correction of subsidence in Work Area 30I required working of almost twice the area originally estimated. In 1971 a new subsidence hole formed.

Work Areas 29 and 30 were contour graded because of the poor condition of the highwall. The revegetation plan called for 2 tons per acre of limestone (applied April-May 1968), 15 lb per acre of _Serecia lespedeza_, 10 lb per acre tall fescue, 10 lb per acre of _tall oat grass_, and 1000 lb per acre of 10-10-10 fertilizer. The seed and fertilizer were applied in May 1968. Hydroseeding (14.8 acres) was used on the steep banks. In addition, six rows of black alder followed by six rows of a grab mixture of scotch and shortleaf pine were hand planted in this area.

A superb growth of fescue developed the first year. By the third year an outstanding growth of _S. lespedeza_ had taken over a large section. Survival of alder _was about 90_ percent. By 1972 these trees were 10 to 14 feet tall. Survival of pine was approximately 70 percent. The pines were about 2 feet tall; the slow growth is probably due to competition with the grass.

By 1976 the survival of black alder had declined from 90 percent to 50 percent because of fungus infection. Many of the alder were over 20 feet tall. White, scotch, and shortleaf pine had about 35 percent survival and the white and scotch were 10 to 15 feet tall. Shortleaf and Virginia pine made up 20 percent of the stand and were 6 to 8 feet tall. Cover of the entire area approached 100 percent (Figure A-10).

Work Area 52--
No work took place in this area because the contract was terminated.

Cost of Reclamation

Records were kept of the equipment and labor used in each work area. These data were used to determine direct costs as reported in Table A-22. The remaining costs were then distributed on a direct-cost percentage basis to the work areas. For cleaning and grubbing, reclamation, and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total cost for each work area is reported in Table A-23.

Results of Reclamation

Backfilling and mine sealing has resulted in the reduction of some of the pollution load. In 1970 and 1971, the total flow past RT 8F-1 was substantially decreased. The vegetative cover and tree growth may account for this reduction.

The concentration figures in Table A-24 show an improvement in water quality due to reclamation. Acidity decreased 60 percent and sulfate decreased 66 percent from 1966 through 1970. In 1971 the acidity load was 77 percent lower and the sulfate, 79 percent lower. Clearly, reclamation has improved the water quality. Underground mine discharges now contribute nearly all of the pollution (see Table A-21).

MIDDLE ROARING CREEK (R-7 TO R-5)

Area Description

The watershed draining into the R-7 to R-5 section of Roaring Creek encompasses 4,237 acres, of which 3,397 acres lie in the Flatbush Fork watershed (discussed earlier). The watershed rises from an elevation of 2,225 feet at R-5 to 2,500 feet on the south side. Roaring Creek drops about five feet between R-7 and R-5, a distance of 1.5 miles. The town of Mabie lies in this watershed.

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Figure A-10. Work Areas 29 and 30, summer of 1976.

Table A-22. COST OF WORK - DIRECT COST (DOLLARS)[a]

Area number	Cleaning and grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment & materials	Labor	
28	1,066	1,904	2,393	521	2,052	3,386	b	b	11,322
29	606	1,627	2,598	1,228	938	337	b	b	7,334
30	3,362	6,662	13,777	2,908	5,955	4,282	b	b	36.946
28-30	5,034	10,193	18,768	4,657	8,945	8,005	8,283	3,175	67,060

[a] For clearing and grubbing, reclamation and underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G&A etc. Revegetation cost includes cost of labor, equipment and materials.

[b] Cost figures not available for revegetation of individual areas.

TABLE A-23. TOTAL COST FOR WORK AREAS (DOLLARS)

Area number	Clearing & grubbing, reclamation, underground	Revegetation	Total	Cost/acre
28	14,693		14,693	
29	9,518		9,518	
30	47,947		47,947	
28-30	72,158	14,112	86,270	1,771

TABLE A-24. SUMMARY OF QUARTERLY DATA FOR STATION RT 8F-1, MOUTH OF SMALL TRIBUTARY

	Sulfate							
	Load in tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1966	0.347	0.201	0.091	0.149	2.9	2.9	2.8	3.1
1967	1.457	0.258	0.045	0.295	3.1			3.3
1968	0.256	0.233	0.003	0.240	3.8	3.7	3.4	3.7
1969	0.615	0.336	0.067	0.053	3.4	3.4	3.2	3.3
1970	0.078	0.068	0.038	0.056	3.5	4.3	3.5	3.6
	Specific conductance in µmhos/cm				Precipitation in inches			
1966	845	1060	1041	622	10.42	12.14	15.06	9.01
1967	710			450	13.79	16.74	16.22	11.43
1968	365	318	490	338	8.73	12.69	11.54	12.15
1969	425	618	447	514	12.69	14.08	19.71	12.22
1970	410	425	446	316	9.22	13.40	17.69	13.55
1971	252	410	303	425	13.45	10.31	19.99	5.45
	Acidity							
	Load in tons				Concentration in mg/l			
1966	22	15	6	5	258	298	258	137
1967	56			28	156			391
1968	5	4	0.1	4	81	70	112	75
1969	30	11	1.5	2	200	141	94	126
1970	2	2	0.8	1	85	135	81	80
1971	2	1.3	3	5	63	61	89	138
	Total Iron							
	Load in tons				Concentration in mg/l			
1966	3	2	1	5	31	34	29	14
1967	6			2	16			22
1968	1	1	0.01	0.4	12	11	11	7
1969	3	3	0.3	0.6	16	19	9	43
1970	0.2	0.1	0.1	0.2	9	8	9	11
1971	0.3	0.1	0.1	2	8	5	3	6

(continued)

TABLE A-24 (continued).

	Sulfate							
	Load in tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1966	27	19	8	9	321	376	353	245
1967	104			16	292			215
1968	9	8	0.1	10	149	145	185	170
1969	38	21	5	5	255	257	280	388
1970	3	2	1	2	148	122	150	113
1971	4	2	1.4	6	109	120	47	170
	Hardness							
	Load in tons				Concentration in mg/l			
1966	11	8	4	4	132	168	168	117
1967	56			8	157			113
1968	6	4	0.1	7	96	75	112	120
1969	24	17	3	3	162	209	156	221
1970	2	3	1	2	119	176	138	164
1971	4			5	118			154
	Calcium							
	Load in tons				Concentration in mg/l			
1966	8	5	2	3	94	106	106	75
1967	34			6	95			81
1968	4	3	0.07	4	61	46	85	71
1969	17	11	2	2	115	138	95	135
1970	1	1	1	1	77	72	99	93
1971	3	2	2	3	73	87	63	95
	Aluminum							
	Load in tons				Concentration in mg/l			
1966	1	0.8	0.3	0.3	16	17	14	9
1967	4			0.7	10			9
1968	0.3	0.3	0.01	0.6	5	6	11	10
1969	1.5	0.8	0.1	0.3	10	10	7	19
1970	0.1	0.15	0.06	0.15	7	10	7	11
1971	0.2			0.14	8			4

Mining Summary and Work Area Description

In addition to mining in the Flatbush Fork and Mabie (RT 8F-1), portions of Work Areas 27, 28, 31 and 45 drain into this region. These are shown in Figure A-11 and discussed individually below.

Work Area 27 - Travise Strip (7 acres)--
Part of this area is in the Flatbush Run watershed (discussed earlier).

Subarea A--An unbackfilled strip, one or two cuts wide. At least 18 caved openings were noted along the highwall. The highwall was broken badly because of the underground mining. Considerable subsidence was present above the highwall.

Subarea B--A strip mine that has been backfilled nearly level and planted in white pine and locust. Eight concealed openings were noted along the highwall. The backfill drained toward the highwall.

Subarea C--A partly caved opening in highwall. The entry was in fair condition without drainage, and the bottom was dry.

Subarea A--A concealed opening in highwall.

Work Area 28 - Strip Mine (3.5 acres)--
Part of this area is in the Mabie watershed (discussed earlier).

Subarea A--A small strip mine with many concealed openings. Much subsidence above the highwall.

Subarea B--A discharging opening (RT 8F-5), average flow - 0.058 cfs, pH - 2.8, acidity - 245 mg/l, iron - 22 mg/l, and sulfate - 558 mg/l.

Work Area 31 - Mabie Mine Strip (19 acres)--
Some of the stripping in this area was done before 1920 to provide entry into the bank for deep mining. Deep mining was completed in early 1930. During the despression, 254 seals were constructed by the WPA. Since that time most of the outcrop has been restripped and the seals destroyed. At present some 88 openings along the highwall are known, 10 of these have discharges. Most of the area atop the highwall is badly subsided.

Part of this area is in the R-7 to R-8 area (discussed earlier).

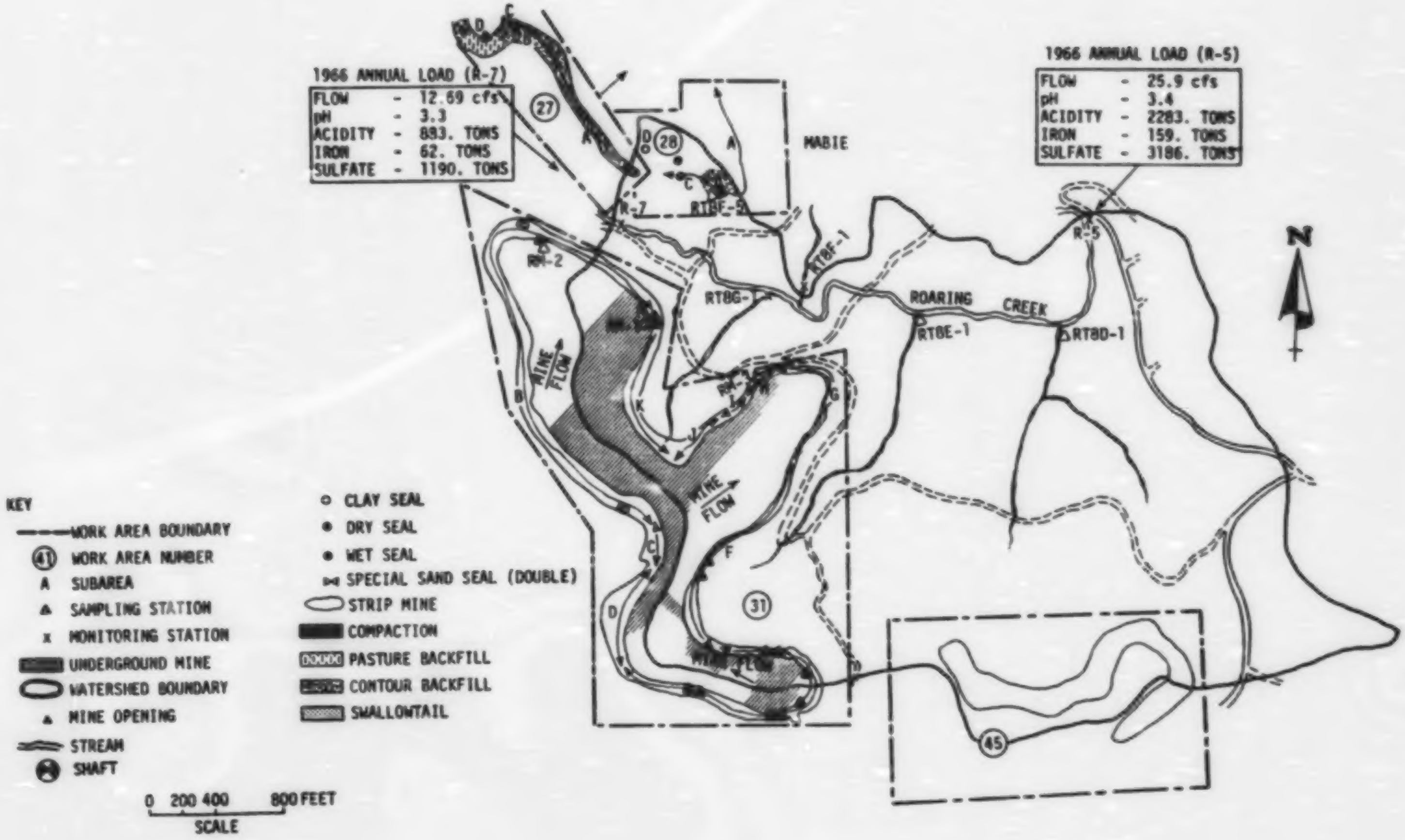
1966 ANNUAL LOAD (R-7)
FLOW - 12.69 cfs
pH - 3.3
ACIDITY - 893. TONS
IRON - 62. TONS
SULFATE - 1190. TONS
1966 ANNUAL LOAD (R-5)
FLOW - 25.9 cfs
pH - 3.4
ACIDITY - 2283. TONS
IRON - 159. TONS
SULFATE - 3186. TONS
N
MABIE
27
28
31
45
R-7
R-5
RM-2
RTBF-5
RTBF-1
RTBG-
RTBE-1
RTBD-1
ROARING CREEK
MINE FLOW
MINE FLOW
MINE FLOW
A
B
C
D
F
G
J
K
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
x MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
SHAFT
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 200 400 800 FEET
SCALE

Figure A-11. Middle Roaring Creek watershed (R-7 to R-5).

Subarea A--Two concealed openings. Main portal of West Virginia Coal and Coke Company's No. 6 mine. A small discharge (Rm-1), flow - 0.035 cfs, pH - 3.0, acidity - 256 mg/l, iron - 32 mg/l, and sulfate - 552 mg/l.

Subarea B--At least 23 concealed openings in the highwall. Considerable subsidence atop the highwall. Discharge RM-2, flow - 2,006 cfs, pH - 3.2, acidity - 99 mg/l, iron - 3 mg/l, and sulfate - 163 mg/l.

Subarea C--Strip with eight or more partially concealed openings in highwall.

Subarea D--Strip with three concealed openings in highwall.

Subarea E--Eight concealed openings along highwall.

Subarea F--Portal and three concealed openings. Main heading of West Virginia Coal and Coke Company's No. 7 mine. Discharge RM-3, flow - 0.060 cfs, pH - 2.8, acidity - 373 mg/l, iron - 46 mg/l, and sulfate - 617 mg/l.

Subarea G--Nine concealed openings along highwall.

Subarea H--Five openings plus 150 feet of 36-foot auger holes along this part of highwall.

Subarea I--Nine or more openings.

Work Area 45 - Strip mine--

There were no deep mine openings along this 3,000 feet of stripping. The strip was on the Middle Kittanning seam of coal. The Lower Kittanning, which is about 10 feet below the Middle Kittanning in this area, has been opened in several areas for prospecting only.

The western end had been adequately backfilled and planted. The eastern half remains unbackfilled, with carbonaceous material exposed on the spoils.

Small tributaries RM-6 and RM-7, characterized below, are located in this area.

	RM-6	RM-7
flow, cfs	0.009	0.021
pH	3.4	3.1
acidity, mg/l	118.0	104.0
iron, mg/l	12.0	4.0
sulfate, mg/l	195.0	196.0

Description of Mine Drainage Problem

Station R-7 was used to monitor the quality and quantity of water entering this watershed by way of the main stem of Roaring Creek. These data are presented in Tables A-25 and A-26. Station R-5 was used to evaluate water leaving the watershed (Tables A-25 and A-26). Between these two points are several tributaries with significant pollution contribution. Table A-27 summarizes contributions of these tributaries for the base year 1966. By far the greatest contribution is from Flatbush Run. Stations RT 8G-1 and RT 8E-1 measure runoff from Work Area 31, and Stations RT 8D-1 from Work Area 45. Not all the drainage from Work Area 31 is measured by RT 8G-1 and RT 8E-1. Because some areas drain directly into Roaring Creek, the contributions from Work Area 31 are greater than 50 and 86 tons per year of acidity and sulfate respectively. Work Area 45 is a minor contributor.

Reclamation Work Performed

Work performed in the various work areas of this watershed is described below.

Work Area 27 - Travise Strip (7 acres)--

The subsidence in Work Area 27A-C was corrected by grading. The surface mine was then graded to a contour backfill. Work Area 27 was considered in more detail earlier in Appendix A (see Flatbush Fork watershed segment). This area can be considered stabilized.

Work Area 28 - Strip Mine (3.5 acres)--

Two seals were constructed in this area. Construction of a wet seal at Work Area 28C required three walls because a cross-cut was present a short distance into the mine; two were solid walls and one was the wet seal. A clay seal was constructed at 28D. The entire area 28B was then graded to a contour backfill. The discussion of Work Area 28 in the Mabie watershed segment of Appendix A gives further details on reclamation and revegetation. The area can be considered stabilized.

TABLE A-25. SUMMARY OF ANNUAL DATA FOR STATION R-7, MIDDLE ROARING CREEK, AND STATION R-5, MIDDLE ROARING CREEK

Year	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Station R-7 Before reclamation				
1964	4.7	38[a]	1.8[a]	81[a]
1965	10.61	216	17	411
1966	12.69	883	62	1,190
After reclamation				
1968	16.6	834	48	1,255
1969	15.95	775	36	770
1970	16.11	564	35	668
1971[b]	25.30	614	22	560

Station R-5 Before reclamation	Flow, cfs	pH	Acidity, tons	Iron, tons	Sulfate, tons
1965	20.64	3.4	936	55	1,808
1966	25.90	3.4	2,283	154	3,186
After reclamation					
1968	34.86	3.8	2,062	137	3,227
1969	24.06	3.8	1,304	68	1,508
1970	32.98	3.9	1,168	98	1,574
1971	103.72	4.2	3,365	136	2,515

[a] Site R-5 is downstream from R-7.

[b] Data for only first 9 months of the year.

TABLE A-26. SUMMARY OF QUARTERLY DATA FOR STATION R-7, MIDDLE ROARING CREEK

Quarter Year	Flow in cfs				pH value			
	1	2	3	4	1	2	3	4
1964	10.20	3.54	0.51	4.74	4.7	4.6	4.3	4.4
1965	28.26	13.29	0.18	0.70	4.4	4.1	3.0	3.0
1966	14.01	20.45	2.34	13.96	3.6	3.5	2.9	3.5
1967	16.29	30.98	6.13	12.39	3.7	3.7	3.5	3.8
1968	18.98	26.28	0.68	20.72	3.9	4.0	3.3	3.7
1969	14.20	11.68	20.03	17.90	4.0	3.9	3.5	3.9
1970	28.83	14.33	4.72	16.58	4.0	3.7	3.8	4.1
1971	33.50	13.68	28.75		4.4	4.1	3.8	
	Specific conductance in µmhos/cm							
1964	50	66	138	112				
1965	75	141	874	756				
1966	243	219	964	229				
1967	163	169	251	139				
1968	177	129	533	222				
1969	140	177	177	223				
1970	115	200	236	155				
1971	75	123	190					
	Acidity							
	Load in tons				Concentration in mg/l			
1964			2	29		8	16	25
1965	61	90	17	48	9	28	371	276
1966	244	251	196	192	71	50	342	56
1967	130	254	95	138	33	33	63	45
1968	259	214	30	331	56	33	182	65
1969	130	146	315	184	37	51	64	42
1970	189	189	46	140	27	54	40	35
1971	89	79	446		11	24	64	
	Iron							
	Load in tons				Concentration in mg/l			
1964		0.5	0.1	1.2		0.6	0.6	1.1
1965	2	8	2	5	0.3	2.3	49	27
1966	14	15	20	13	4	3	34	4
1967	10	17	7	8	2	2	4	3
1968	15	8	2	23	3	1.3	11	5
1969	5	8	12	11	1.5	3	2.5	2.6
1970	12	9	3	11	1.6	2.7	2.9	2.6

(continued)

TABLE A-26 (continued).

Quarter	Sulfate							
	Load in tons				Concentration in mg/l			
Year	1	2	3	4	1	2	3	4
1964		16	5	60		19	41	52
1965	182	154	17	58	26	47	362	334
1966	318	392	219	261	92	78	380	76
1967	196	350	128	144	49	46	85	48
1968	348	303	37	567	75	47	222	112
1969	163	154	289	164	47	54	59	37
1970	213	238	73	144	30	68	63	35
1971	179	123	258		22	37	37	
	Hardness							
	Load in tons				Concentration in mg/l			
1964		34	0.7	7		14	20	29
1965	147	81	6	23	21	24	120	131
1966	128	179	72	139	37	35	125	40
1967	113	169	61	105	28	22	40	34
1968	126	168	14	286	27	26	86	56
1969	138	142	226	130	39	49	46	29
1970	180	56	51	181	25	16	44	44
1971	203	73			25	22		
	Calcium							
	Load in tons				Concentration in mg/l			
1964		18	0.4	4		8	11	17
1965		41	3	13		13	63	75
1966	80	97	34	82	23	19	60	24
1967	40	87	35	51	14	11	23	17
1968	69	98	9	144	15	15	51	28
1969	89	92	120	75	26	32	25	17
1970	101	51	27	92	14	15	23	23
1971	113	40	126		14	12	18	
	Aluminum							
	Load in tons				Concentration in mg/l			
1964		0.8	0.02	0.2		0.3	0.4	0.7
1965		8	1	4		2	28	24
1966	19	21	17	15	6	4	29	4
1967	9	23	8	10	3	3	6	3
1968	36	18	4	61	8	3	23	12
1969	20	15	24	22	6	5	5	5
1970	23	7	8	16	3	2	7	4
1971	16	7			2	2		

TABLE A-27. POLLUTION CONTRIBUTION OF TRIBUTARIES TO MIDDLE ROARING CREEK BETWEEN STATIONS R-7 AND R-5 FOR THE BASE YEAR 1966

	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Main stream				
R-7	12.69	883	62	1,190
R-5	25.90	2,283	154	3,186
Tributary				
Flatbush, RT9-23	10.325	687	42	1,046
RT8G-1	0.192	39	6	71
RT8F-1	0.197	47	5	63
RT8E-1	0.154	11	0.2	15
RT8D-1	0.253	11	1.9	13

TABLE A-28. CHARACTERISTICS OF MINE SEAL STATION RT8F-5

Year	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Before reclamation				
1965	0.031	5	0.5	15
1966	0.058	14	1.4	32
After reclamation				
1968	0.080	20	3	42
1969	0.087	23	3.5	45
1970	0.097	19	2.5	41
1971[a]	0.183	20	1.8	39

[a] Data for 1st nine months of the year only.

Work Area 31 - Mabie Mine Strip (19 acres)--

A limited amount of work was performed in Work Areas 31A and K. When collapse of the highwall caused the death of a shovel operator, Work Area 31 was re-evaluated, with the conclusion that fractures of the highwall made it unsafe and that work would be discontinued. Termination of the project curtailed any further work except for contour grading of 10.5 acres already disturbed and planting of 31 acres in black alder, cottonwood, scotch pine, shortleaf pine, Virginia pine and white pine. The planting took place in May 1968.

Work Area 45 - Strip Mine--

This area was to have been pasture backfilled. Because the project ended, no work was performed.

Cost

Cost figures for Work Area 27 were shown earlier in Table A-19 and for Work Area 28 in Table A-22. Costs for the work performed in Work Area 31 were as follows:

Direct Cost:	Dollars
Cleaning and grubbing	4,991
Reclamation operation	12,215
Underground operation	574
Revegetation	344
Total	18,124
Indirect cost	5,392
Total cost	23,516
Cost/acre	2,240

Results

Any improvement in the watershed would be due to the reclamation in Flatbush Run, the Mabie area and Work Area 27-28, which was only 19.6 acres. Table A-25 shows a significant decrease (about 50%) in acidity and sulfate levels at Station R-5. A part of this decrease is due to reduced amounts of water entering the watershed at R-7.

The wet mine seal in Work Area 28 (RT 8F-5) has not resulted in a decrease in pollution level (see Table A-28). The flow has increased because of the reclamation. Water that formerly seeped out at several points along the highwall has now been forced out through the wet seal.

MABIE - COALTON SECTION OF ROARING CREEK (R-5 TO R-3)

Area Description

The watershed draining the Mabie - Coalton section of Roaring Creek encompasses 4,090 acres (Figure A-12). The watershed rises from an elevation of 2,150 feet at Coalton to 3,517 at the crest of Rich Mountain on the east. Roaring Creek drops 75 feet between Stations R-5 and R-3, a distance of 3.6 miles. The town of Coalton is located in the watershed; most of the area, however, is sparsely populated and forest-covered.

Mining Summary and Work Area Description

A total of 210 acres or 5.1 percent of the watershed has been surface-mined. All but 52.8 acres of this surface mining was in the Sewell seam near the crest of Rich Mountain. This seam produces a low level of pollution and was not included in the reclamation plans for this demonstration project.

This watershed includes Work Areas 11 and 44. Specific details of this watershed follow.

Work Area 11 - South Coalton Strip (42.4 acres)--
The large underground mine complex lay adjacent to this strip area. At least 30 concealed openings were found along the highwall and there may have been many more. No drainage from any of the openings was noted. It was apparent that water was directed from the strip pit into the underground workings and subsequently drains at discharges RT 6A-1 (Work Area 53), RT 6-5 (Work Area 13), RT 6-3 (Work Area 12), RT 6-2A (Work Area 12), and RT 8B-3 (Work Area 44). The top of the highwall shows no indication of subsidence. The strip has not been backfilled.

Subarea A--A mine opening beyond the end of the strip that was sealed under WPA (WPA Seal No. 5453). A discharge of 0.009 cfs and pH 7.0 were measured. Adjacent area was subsided.

Subarea B--A mine opening sealed by WPA (Seal No. 5354). There was no discharge from this seal. Some subsidence was noted.

Subarea C--A large deposit of exposed carbonaceous material.

Work Area 44 - Fisher Strip Mine (10.4 acres)--
The large underground complex lay adjacent to this strip area. Water directed to the underground mine from the surface mines probably discharged at RT 6-5 (Work Area 13) and RT 6-6A (Work Area 15).

Subarea A--WPA mine seal No. 5362. Seepage from seal had a pH of 6.5 and flow less than 0.002 cfs.

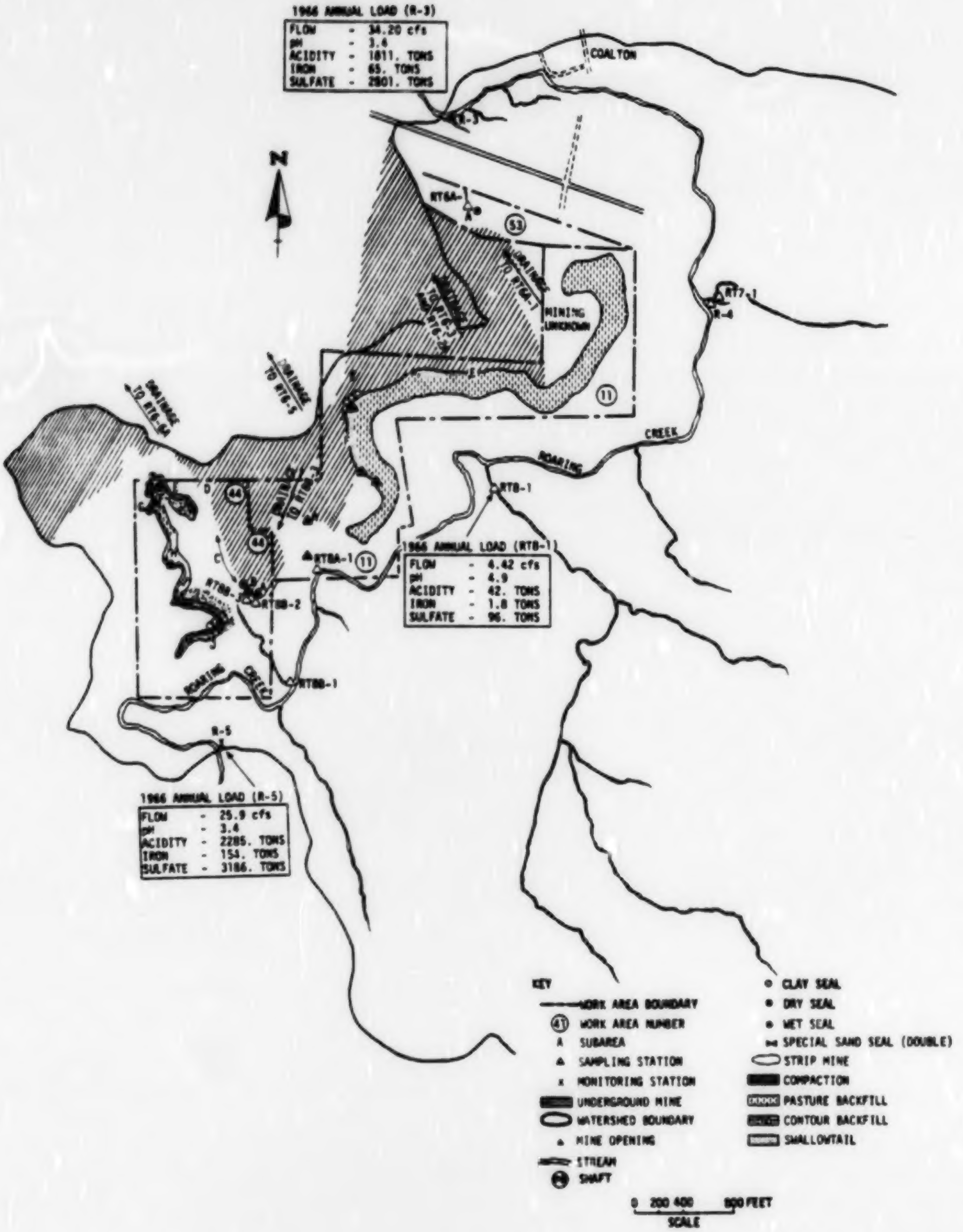
1966 ANNUAL LOAD (R-3)
FLOW - 34.20 cfs
pH - 3.6
ACIDITY - 1011. TONS
IRON - 65. TONS
SULFATE - 2801. TONS
COALTON
R-3
N
RTGA-1
53
DRAINAGE TO RTGA-1
MINING UNKNOWN
RT7-1
R-4
11
DRAINAGE TO RTG-6A
DRAINAGE TO RTG-5
CREEK
ROARING
RTB-1
D
44
C
RTBA-1
RTBB-3
RTBB-2
RTBB-1
ROARING CREEK
1966 ANNUAL LOAD (RTB-1)
FLOW - 4.42 cfs
pH - 4.9
ACIDITY - 42. TONS
IRON - 1.8 TONS
SULFATE - 96. TONS
R-5
1966 ANNUAL LOAD (R-5)
FLOW - 25.9 cfs
pH - 3.4
ACIDITY - 2285. TONS
IRON - 154. TONS
SULFATE - 3186. TONS
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
SHAFT
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 200 400 800 FEET
SCALE

Figure A-12. Mabie-Coalton section of Roaring Creek (R-5 to R-3).

Subarea B--Opening 30 feet west of Subarea A which is 14 feet wide with 1 foot of water impounded on the bottom. Local residents use this water for drinking and stock watering. Average discharge - 0.084 cfs, pH - 3.5, acidity - 37 mg/l, iron - 1 mg/l, and sulfate - 219 mg/l (RT 8B-3).

Subarea C--This area has been stripped and contour backfilled.

Subarea D--An area of subsidence.

Subarea E--An 800-foot strip mine with all drainage directed to the highwall where it entered the underground mine opening (Subarea F).

Subarea F--A 16-foot opening received drainage from Work Areas 44 E, H, and I. There was also a wet weather stream that flowed over the highwall directly above this opening and into it. There was little overburden between the tributary and the underground mine; water probably percolated into the mine from the tributary for an extended distance above the highwall.

Subarea G--A 16-foot opening in the highwall. Some coal was being removed.

Subarea H--An 800-foot strip with at least 10 concealed openings in the highwall. Spoil was level, but water still drained to opening F.

Subarea I--Strip with 20 or more concealed openings in the highwall. This was a level, clean backfill without indication that water flowed into mine openings. Area above highwall was subsided.

Subarea J--Strip with 14 or more concealed openings in highwall. Portal of Brady Mine is located in this area. An 8- to 10-foot parting develops in the part of the watershed between the Middle and Lower Kittanning. Strip was fairly level but was covered with carbonaceous material.

Work Area 53 - Coalton Area--

This outcrop has not been stripped because the underground mine has been driven almost to the outcrop. The area showed extensive subsidence.

Subarea A--An abandoned mine caved at portal with a discharge (RT 6A-1), average flow - 0.031 cfs, pH - 2.6, acidity - 658 mg/l, iron - 80 mg/l, and sulfate - 574 mg/l. There was a possible parallel opening 100 feet to the east.

Description of Mine Drainage Problem

Sampling Station R-5 was used to monitor the quality and quantity of water entering this watershed by way of the main stem of Roaring Creek. These data are presented in Tables A-29 and A-31. Station R-3 was used to survey the water leaving the watershed (Tables A-29 and A-30). The data collected before reclamation indicated that Roaring Creek picked up little if any additional pollution load in this stretch. To further verify this finding, the pollution loads of the four major tributaries were evaluated. As shown in Table A-32, these tributaries contribute a minor amount of pollution.

To illustrate the pollution contribution of the Sewell seam stripping operation on Rich Mountain, Laurel Run was monitored (RT 8-1). This watershed contained the largest tract of the Sewell strip mines, 127 acres or 6.3 percent of the watershed. As shown in Table A-33, the contribution was small. An increase in 1969 and 1970 was due to new stripping operations that started in 1969.

Reclamation Work Performed

Reclamation work performed in the various work areas of this watershed is described below.

Work Area 11 - South Coalton Strip (47 acres)--

The reclamation plan for this area was to bury the carbonaceous material in Work Area 11C in the strip pit, place clay seals in the larger openings, compact the backfill along the sections of badly fractured highwall, and grade to a pasture backfill. The original estimate was that 264,000 cubic yards of common excavation, 900 cubic yards of subsidence excavation, and 2,200 cubic yards of compacted backfill would be required. Final calculations showed that common excavation amounted to 259,207 cubic yards. There was no excavation for subsidence and 7,040 cubic yards of excavation was required for compacted backfill. Therefore, excavation was 853 cubic yards less than originally estimated.

Three clay seals were constructed at Work Area 11B by clearing the highwall and compacting clay into the openings.

A borrow area was developed at Work Area 11E to cover the carbonaceous material at Work Area 11C that was not buried in the strip pit.

Approximately 1,600 feet of compacted backfill was installed at Work Area 11F.

TABLE A-29. SUMMARY OF ANNUAL DATA FOR STATION R-3, MIDDLE ROARING CREEK, AND STATION R-5, MIDDLE ROARING CREEK[a]

Year	Flow, cfs	pH	Acidity, tons	Iron, tons	Sulfate, tons
Station R-3					
Before reclamation					
1965	29.6	3.6	921	47	1,848
1966	34.20	3.4	1,811	65	2,801
After reclamation					
1968	42.29	3.8	1,455	52	2,546
1969	33.79	3.9	1,573	53	1,621
1970	37.80	4.0	925	92	1,433
1971	101.30	4.1	4,766	120	2,700
Station R-5					
Before reclamation					
1965	20.64	3.4	936	55	1,808
1966	25.90	3.4	2,283	154	3,186
After reclamation					
1968	34.86	3.8	2,062	137	3,227
1969	24.06	3.8	1,304	68	1,508
1970	32.98	3.9	1,168	98	1,574
1971[b]	103.72	4.2	3,395	136	2,515

[a] Site R-3 is downstream from R-5.

[b] Data for first three quarters of the year only.

TABLE A-3C. SUMMARY OF QUARTERLY DATA FOR STATION R-3, MIDDLE ROARING CREEK

Quarter	Flow in cfs				pH value			
	1	2	3	4	1	2	3	4
Year								
1965	80.86	33.54	0.94	3.10	3.8	3.6	3.5	3.1
1966	34.83	52.28	8.11	40.58	3.5	3.5	3.0	3.5
1967	112.50	73.10	13.69	43.47	3.7	3.7	3.5	3.9
1968	52.08	76.73	3.76	36.57	4.0	4.0	3.7	3.8
1969	34.58	22.87	46.71	31.00	4.1	3.9	3.7	4.0
1970	71.33	34.17	9.73	35.95	3.9	3.8	4.0	4.2
1971	85.58	26.10	250.00	43.50	4.2	4.1	4.2	4.1
	Specific conductance in µmhos/cm							
1965	178	197	354	631				
1966	234	229	642	221				
1967	201	198	337	134				
1968	155	136	283	218				
1969	191	177	198	166				
1970	161	170	183	128				
1971	183	111	153	170				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	532	244	11	134	27	30	47	177
1966	476	556	307	472	54	43	155	47
1967	980		346	375	36		103	35
1968	419	536	60	440	33	29	66	49
1969	307	218	829	219	36	39	72	29
1970	525	223	58	119	30	27	25	14
1971	187	127	3578	834	9	20	59	79
	Iron							
	Load in tons				Concentration in mg/l			
1965	31	9	0.2	7	1.5	1.1	1.0	9
1966	17	16	12	20	2.0	1.3	6	2.0
1967	59		13	12	2.2		4	1.1
1968	17	13	2	20	1.3	0.7	[illegible]	2.2
1969	14	11	16	12	1.6	1.9	1.4	1.6
1970	45	18	7	22	2.6	2.2	2.8	2.5
1971	42	4	67	7	2.0	0.6	1.1	0.7

(continued)

TABLE A-30 (continued).

Quarter Year	Load in tons 1	Load in tons 2	Load in tons 3	Load in tons 4	Concentration in mg/l 1	Concentration in mg/l 2	Concentration in mg/l 3	Concentration in mg/l 4
	Sulfate							
1965	1,125	519	26	178	57	63	111	234
1966	691	979	405	726	79	76	204	73
1967	1,773		559		64		164	156
1968	775	850	97	824	61	45	106	92
1969	410	236	708	267	48	42	62	35
1970	822	240	96	275	47	29	40	31
1971	394	158	1515	633	19	25	25	60
	Hardness							
1965	770	324	17	84	38	39	73	110
1966	332	469	192	726	37	36	96	45
1967	1,099		185	416	39		55	39
1968	396	580	51	475	31	30	55	53
1969	397	259	615	323	46	46	53	42
1970	682	235	95	401	39	28	39	45
1971	648	171		644	31	27		61
	Calcium							
1965		212	10	47		26	42	62
1966	202	260	96	259	23	20	48	26
1967	546		119	227	20		36	21
1968	226	354	32	245	18	19	35	27
1969	266	155	363	172	31	27	32	23
1970	405	172	57	217	23	21	24	25
1971	311	89	1334	338	15	14	22	32
	Aluminum							
1965		21	0.9	12		2.6	3.7	16
1966	33	39	25	39	3.7	3.0	13	4
1967	93		32	28	3.3		9	2.6
1968	36	41	6	68	2.8	2.1	7	8
1969	37	17	59	32	4.3	3.0	5	4.2
1970	74	17	7	31	4.2	2.0	3.0	3.5
1971	60	15		32	2.9	2.3		3.0

TABLE A-31. SUMMARY OF QUARTERLY DATA FOR STATION R-5, MABIE-COALTON SECTION OF ROARING CREEK

Quarter	Flow in cfs				pH value			
	1	2	3	4	1	2	3	4
Year								
1965	55.68	24.32	0.35	2.19	3.8	3.4	3.1	3.0
1966	26.43	36.84	10.98	29.36	3.5	3.4	2.8	3.4
1967	79.61	56.06	9.59	23.52	3.6	3.6	3.5	3.8
1968	34.52	58.05	1.66	45.20	3.8	4.0	3.3	3.6
1969	24.14	18.82	31.63	21.63	4.0	3.7	3.5	3.9
1970	58.83	25.33	7.93	39.82	3.9	3.6	3.8	4.1
1971	68.75	22.32	220.08		4.2	4.2	4.1	
	Specific conductance in µmhos/cm							
1965	191	299	679	751				
1966	263	266	955	279				
1967	236	251	336	164				
1968	187	146	493	303				
1969	180	225	210	178				
1970	155	226	241	151				
1971	97	134	180					
	Acidity							
	Load in tons				Concentration in mg/l			
1965	447	340	15	134	33	57	173	250
1966	455	550	821	457	70	61	305	63
1967	891	627	184	291	47	46	78	51
1968	387	520	67	1088	46	37	165	98
1969	266	278	524	236	45	60	68	45
1970	488	312	75	293	34	50	39	30
1971	233	119	3043		14	22	57	
	Iron							
	Load in tons				Concentration in mg/l			
1965	26	17	1	11	2	3	10	20
1966	23	26	77	28	4	3	29	4
1967	67	34	9	19	4	2	4	3
1968	23	21	2	91	3	1	6	8
1969	15	16	23	14	3	3	3	3
1970	39	16	5	38	3	3	2	4
1971	23	6	107		1	1	2	

(continued)

TABLE A-31 (continued).

	Sulfate							
	Load in tons				Concentration in mg/l			
Quarter Year	1	2	3	4	1	2	3	4
1965	950	667	23	168	70	112	268	314
1966	636	833	971	746	98	92	361	104
1967	1561	1085	311	401	83	79	132	70
1968	631	804	89	1703	75	57	218	154
1969	401	325	522	260	68	70	67	49
1970	467	179	1868	-	28	33	35	-
	Hardness							
	Load in tons				Concentration in mg/l			
1965	586	369	13	74	42	61	152	137
1966	284	408	420	463	43	45	156	64
1967	872	548	170	286	46	39	72	49
1968	340	441	38	842	40	31	93	76
1969	322	291	417	248	54	63	52	46
1970	575	211	91	513	39	34	46	52
1971	634	152	-	-	38	28	-	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	271	8	41	-	45	89	77
1966	165	238	200	263	25	26	74	37
1967	449	291	93	154	24	21	40	27
1968	195	266	23	434	23	19	57	39
1969	208	180	228	145	35	39	29	27
1970	332	263	57	263	23	42	29	27
1971	306	105	1250	-	18	19	23	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	43	1	12	-	7	14	22
1966	39	40	66	37	6	4	24	5
1967	84	57	17	33	4	4	7	
1968	37	43	7	178	4	3	18	16
1969	35	25	43	29	6	5	6	6
1970	62	19	9	50	4	3	5	5
1971	67	16	-	-	4	3	-	-

TABLE A-32. POLLUTION CONTRIBUTION OF TRIBUTARIES TO MABIE-COALTON SECTION OF ROARING CREEK, STATIONS R-3 TO R-5 (BASE YEAR 1966 YEARLY AVERAGES)

	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Main stream				
R-5	25.899	3,181	249	4,169
R-3	35.201	2,520	93	3,629
Tributary				
RT 8B-1	0.119	11.9	1.7	25
RT 8A-1	0.046	1.9	0.09	5.8
RT 8-1	4.423	41.9	1.8	102
RT 7-1	2.165	22.9	0.6	12.8

TABLE A-33. CHARACTERISTICS OF STATION RT 8-1, LAUREL RUN RUNOFF

	1965	1966	1967	1968	1969	1970
Flow, cfs	4.422	4.423	6.957	5.545	5.312	3.632
pH	4.5	4.9	5.1	5.4	4.8	5.2
Acidity, mg/l	6	9	5	5	12	12
Acidity, tons	21	42	30	25	61	44
Iron, mg/l	0.38	6	0.3	0.3	3	1.6
Iron, tons	2.6	1.8	2.2	1.1	15	6
Sulfate, mg/l	25	24	14	15	25	32
Sulfate, tons	81	96	94	76	133	207

Except for the borrow in Work Area 11E, which was contour backfilled, the remainder of the disturbed area was pasture backfilled.

The entire area received between 2 and 3.5 tons per acre of agricultural lime in May and June of 1968. In June 1968, 1,000 pounds of 10-10-10 fertilizer, 18 lb/acre of birdsfoot trefoil, 5 lb/acre of sweet clover, 10 lb/acre of tall fescue, 8 lb/acre of Kentucky bluegrass, and 1 lb/acre of reed canary grass were applied. An outstanding growth of grass developed. A good stand of trefoil, sweet clover, and fescue, with lesser amounts of bluegrass, was still present in 1971. This area may be considered stabilized.

Work Area 44 - Fisher Strip Mine (26.7 acres)--

Although the strip mine covered only 10.4 acres, a total of 26.7 acres was disturbed during reclamation. Most of the extra acreage was in subsidence areas.

The reclamation plan was to stop the drainage into opening F by regrading the strip mines and constructing a concrete channel over the highwall and across the spoil to prevent the small stream from entering the underground mine. In addition, the subsidence areas would be corrected, the carbonaceous material buried, and a wet seal constructed at Work Area 44B (RT 8B-3). The spoil was to be graded to facilitate rapid runoff and prevent water from entering the underground mine. The following figures represent the estimated and actual excavation.

	Estimated	Performed	Difference
Common, cu. yd.	36,000	50,877	+14,877
Subsidence, cu. yd.	14,000	25,903	+11,903
Compaction, cu. yd.	6,400	7,413	+1,013
Total, cu. yd.	56,400	84,193	+27,793

Five dry seals, two clay seals, and one wet seal were constructed. In Work Area 44J, two clay seals were constructed to plug the Brady Mine openings. One dry seal was installed in the opening at Work Area 44G. It was of standard construction (see Upper Kittle Run segment of Appendix A). Three additional dry seals were constructed in the openings at Work Area 44F. A wet seal was constructed at Work Area 44B. This seal was different from the standard wet seals constructed because instead of building an outly wall to create a water seal, two 20 foot lengths of 4-inch-diameter plastic pipe were placed through the wall. Two 90 degree elbows were placed at the ends of the pipes to serve as air locks. This type of construction was used because insufficient room was available to build the front wall.

Following the construction of the dry seals at Work Area 44F, 600 feet of compacted backfill was placed against the highwall in Work Areas 44 F-H. The subsidence was then corrected and a contour backfill installed. The original plan was to construct 500 feet of concrete-lined channel to carry the stream over Work Area 44F. With termination of the project, it was necessary to develop a modified plan. The stream channel was lined with compacted clay and covered with crushed limestone.

The subsidence in Work Area 44D was not corrected because of the project termination. A large pile of carbonaceous material was moved from Work Area 44E to 44I and buried in the pit. In Work Area 44J a large subsidence area was backfilled. A contour backfill was installed in Work Areas 44 J and E and a pasture backfill in Work Areas 44 H and I.

In May 1968, 2 tons per acre of agricultural limestone was applied to the reclaimed areas. On the steep areas, such as Work Area 44J, and along the reconstructed channel, 10 lbs/acre of Serecia lespedeza, 5 lb/acre of love grass, 10 lb/acre of Kentucky bluegrass, 5 lb/acre of orchard grass, 1,000 lb/acre of mulch, and 1,000 lb/acre of 10-10-10 fertilizer were hydroseeded in May 1968. The area was then overplanted with six rows of black alder, followed by six rows of a grab mixture of tulip poplar, cottonwood, and white oak. On the level areas the same amount of fertilizer was used and the following grasses were planted: tall fescue - 4 lb/acre, Kentucky bluegrass - 24 lb/acre, S. lespedeza - 4 lb/acre, and orchard grass - 5 lb/acre. No trees were planted.

A vigorous growth of love grass developed in the hydroseeded area the first year. An excellent stand of fescue and orchard grass also took over the level areas. The stand was so good that a local farmer turned in farm animals, whose grazing almost destroyed the grass. By 1971 the love grass had died out and had been replaced by a very heavy stand of S. lespedeza.

Visual observations of the rock channel have revealed no washing deterioration.

Work Area 53 - Coalton Area--
The only work conducted in Work Area 53 was the construction of a standard wet seal at Subarea A (RT6A-1).

Cost of Work

Direct costs are shown in Table A-34 and total costs for each work area are reported in Table A-35.

TABLE A-34. COST OF WORK - DIRECT COST[a]

Area No.	Clearing & grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment & material	Labor	
11	284	2,066	54,564	8,712	1,000	399	5,500	1,901	74,426
44	1,515	1,909	8,163	4,153	7,298	6,274	6,052	1,266	37,630
53	-	-	493	70	860	940	-	-	2,363

[a] For clearing and grubbing, reclamation, and underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G&A, etc. Revegetation cost includes cost of labor, equipment and materials.

TABLE A-35. TOTAL COST FOR WORK AREAS

Area Number	Clearing & grubbing reclamation, underground	Revegetation	Total	Cost/Area
11	86,982	9,177	96,159	2,046
14	39,338	8,973	48,311	1,809
53	3,067	-	3,067	-

Results of Reclamation

As indicated earlier, the mining operations in this watershed had only a minor effect on Roaring Creek; therefore, the reclamation work cannot be expected to make a significant change in water quality. From Table A-29, it can, indeed, be concluded that this was the case. Since a significant amount of the reclamation was performed in Work Area 44, an evaluation of the water quality and quantity of water discharging from the area should indicate the effectiveness of reclamation. In Work Area 44, the mine water had been directed into the underground mine, thus, the pollution from the area appeared small. Reclamation to prevent this water from entering the mine should result in an increase in flow. As shown in Table A-36, flow did increase in 1968 and 1969, and possibly in 1971. The low flow in 1970 cannot be explained.

As shown in Table A-37, the wet seals were not effective in reducing the pollution load.

UPPER KITTLE RUN WATERSHED (RT6-21)

Area Description

The Upper Kittle Run drainage basin contains 399 acres. It is a pear-shaped watershed, bordered on the southwest by State Routes 4 and 17 (Figure A-13). Kittle Run flows easterly into Roaring Creek at Coalton, West Virginia. The gaging station for the Upper Basin, RT 6-21, is 0.72 miles upstream from the mouth. Elevations range from 2,185 feet at the mouth of Upper Kittle Run to 2,470 feet on the hilltops. The mainstem of the stream is 1.07 miles long, falling at the rate of 0.019 ft/ft from the headwaters. The entire basin measures 1.05 by 0.77 miles.

Mining Summary and Area Description

Strip mines of the 1940's and 50's account for 71 acres or 18 percent of the surface area. During these stripping operations, 18,500 feet of highwall were exposed. As work continued on the demonstration project, all of the land was reclaimed. Working of the large strip mine complex in the area intercepted and destroyed the original channel of Kittle Run. Part of the reclamation work was aimed at reforming the stream bed.

The whole watershed was underlaid by part of the large drift mine (3,000 acres) extending to Norton. These old workings were intercepted by the strip mines in several locations. At one point, two shafts lead to three hallways, which cross under Kittle Run and carry water northward to Grassy Run (GT 6-1). These shafts were once used for transporting the strip mine coal by mine car through the deep mine to the tipple at Norton to reduce transportation costs. At another point, water drained

TABLE A-36. CHARACTERISTICS OF RUNOFF FROM AREA 44 (RT 8B-1)

Year	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Before reclamation				
1965	0.081	1.6	1.5	8
1966	0.119	11.9	1.7	25
After reclamation				
1968	0.303	26	4.7	60
1969	0.311	8	2.0	37
1970	0.074	0.5	0.1	7
1971[a]	0.143	1.3	0.3	12.6

[a] Data are for first half of the year only.

TABLE A-37. CHARACTERISTICS OF MINE SEALS RT 6A-1 AND RT 8B-3

Year	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Station RT 6A-1				
Before reclamation				
1965	0.017	7	0.4	9
1966	0.031	20	2.5	18
After reclamation				
1968	0.026	12	1.1	13
1969	0.017	8	0.9	9
1970	0.020	8	0.7	11
1971				

Year	Flow cfs	Acidity Tons	Iron Tons	Sulfate Tons
Station RT 8B-3				
Before reclamation				
1965	0.051	2.1	0.06	11
1966	0.084	3	0.05	18
After reclamation				
1968	0.122	2.5	0.1	18
1969	0.074	2.5	0.2	23
1970	0.086	2.2	0.3	9

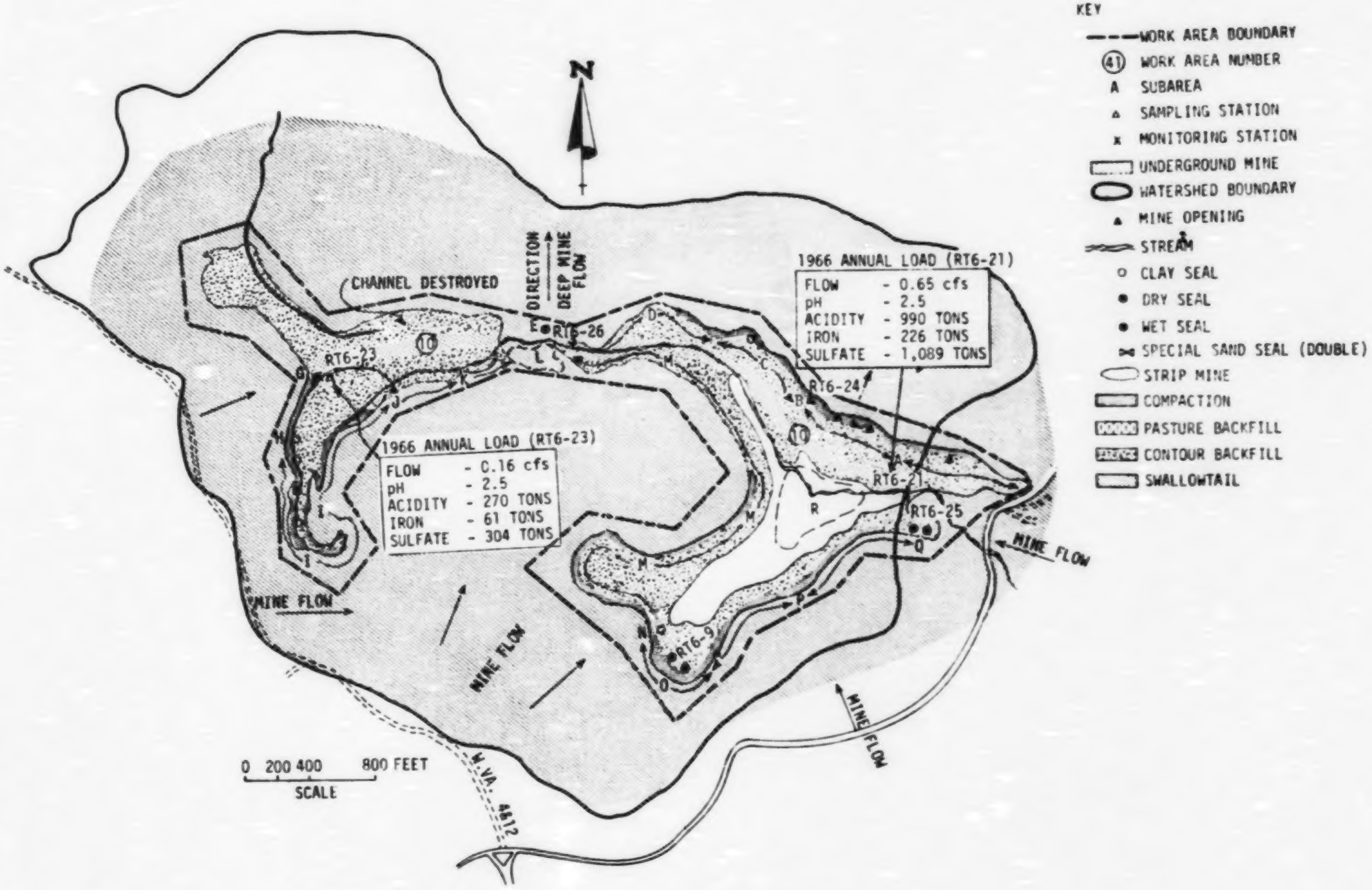
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
N
CHANNEL DESTROYED
DIRECTION DEEP MINE FLOW
1966 ANNUAL LOAD (RT6-21)
FLOW - 0.65 cfs
pH - 2.5
ACIDITY - 990 TONS
IRON - 226 TONS
SULFATE - 1,089 TONS
1966 ANNUAL LOAD (RT6-23)
FLOW - 0.16 cfs
pH - 2.5
ACIDITY - 270 TONS
IRON - 61 TONS
SULFATE - 304 TONS
RT6-23
RT6-26
RT6-24
RT6-21
RT6-25
RT6-9
10
MINE FLOW
MINE FLOW
MINE FLOW
MINE FLOW
W.VA. 46/2
0 200 400 800 FEET
SCALE

Figure A-13. Upper Kittle Run watershed (RT6-21).

from the strip pit on the north side of the subwatershed into exposed underground mines (RT6-24) and eventually discharged to White's Run (RT-5-2).

The watershed contains only one work area, number 10. This is one of the largest and most complex. Four acres of Work Area 10 are actually in the Lower Kittle Run watershed, but will be included in this discussion. Subareas are shown on Figure A-13 and described below.

Work Area 10 - Upper Kittle Run--

Subarea A--Twenty or more concealed openings along the highwall, which was used as a garbage dump.

Subarea B--A 3-foot opening draining impounded water from the strip into the deep mine.

Subarea C--A strip with 16 openings allowing possible drainage into the mine.

Subarea D--A clean strip with no indications of concealed openings.

Subarea E--A 20-foot shaft into the deep mine.

Subarea F--2,500 feet of stripping. There were no apparent openings in the highwall.

Subarea G--A 16-foot caved opening impounding 2 feet of water in the mine. Average discharge (RT6-23) - 0.157 cfs, pH - 2.5, acidity - 1887 mg/l, iron - 430 mg/l.

Subarea H--A concealed opening with seepage discharge (RT 6-16), flow less than 0.06 cfs, pH - 2.5, acidity - 1700 mg/l, iron - 390 mg/l.

Subarea I--A 2,000-foot strip with at least two concealed openings. Several tributaries have been intercepted and there is considerable subsidence.

Subarea J--A concealed opening.

Subarea K--A 1,000-foot strip with several openings and pools along the highwall.

Subarea L--An extreme subsidence area, which had not been stripped.

Subarea M--A 3,500-foot strip with no apparent openings in the highwall. Maps indicated that there may be many concealed openings.

Subarea N--A 16-foot-wide entry in the highwall issuing an average discharge (RT 6-9) of 0.033 cfs, pH - 2.3, acidity - 2000 mg/l, and iron - 470 mg/l.

Subarea O--400 feet of stripping with at least five concealed openings in the highwall.

Subarea P--A 1,500-foot strip with at least 19 highwall openings.

Subarea Q--A 16-foot opening with a concrete block wall constructed halfway across. Water was impounded 2 feet deep.

Subarea R--A large swamp.

Description of Mine Drainage Problem

The drainage problem in Upper Kittle Run was compounded by the fact that both sides of the hollow were stripped and the spoil deposited in the center, thereby destroying the stream channel. Water from the upper portions of the watershed was diverted and partly drained into the deep mine workings. This flow in turn increased the pollution load in White's Run and Grassy Run. At Station RT 6-21, the acidity, iron, and sulfate concentrations averaged 1,300 mg/l, 306 mg/l, and 1,563 mg/l respectively in 1966. Total loads of 990 tons, 226 tons, and 1,089 tons were recorded. Rainfall for the year was 47.14 inches (Table A-38 gives complete yearly data). Two major deep mine openings, RT 6-9 and RT 6-23 were discharging 335 tons of acid or 34 percent of the total. The prereclamation figure for measurable surface mine acid production was thus 655 tons.

For the base year of 1966, the deep mine drainage contributed almost one-third of the measurable flow, with high concentrations of acid, iron, and sulfate. Station RT 6-9 yielded yearly average values of 1,998 mg/l acidity, 472 mg/l iron, and 2,709 mg/l sulfate. The effluent at Station RT 6-23 yielded 1,888 mg/l acidity, 435 mg/l iron and 2,097 mg/l sulfate (see Tables A-39, 40, and 41).

Reclamation Work Performed

The work performed in this watershed (includes Work Area 10 only) is described below.

Work Area 10 - Upper Kittle Run--

On the north side of the watershed in Work Area 10, a contour-type backfill was established by reducing the heavily fractured highwall and moving material from the center of the hollow to complete the backfilling operation. On the south side of the hollow, a pasture-type backfill was established. Prior to backfilling, drainage ditches were established in both

TABLE A-38. SUMMARY OF ANNUAL DATA FOR STATION RT 6-21, UPPER KITTLE RUN, STATION RT 6-23, DEEP MINE DISCHARGE, AND STATION RT 6-9, DEEP MINE DISCHARGE

Year	Rainfall, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station RT 6-21					
Before reclamation					
1965	37.77	0.116	684	149	849
1966	47.14	0.153	990	226	1,089
After reclamation					
1968	41.46	0.168	730	205	765
1969	42.58	0.142	686	212	882
1970	42.60	0.118	458	143	685
1971	37.92	0.296	861	236	965
		Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station RT 6-23					
Before reclamation					
1965[a]		0.045	312	69	379
1966		0.038	270	61	304
After reclamation					
1968		0.043	244	72	232
1969		0.036	199	60	242
1970		0.037	186	52	248
1971[b]		0.037	165	46	190
Station RT 6-9					
Before reclamation					
1965[a]		0.010	53	13	60
1966		0.008	65	15	93
After reclamation					
1968		0.042	265	69	249
1969		0.036	243	69	251
1970		0.029	181	48	216
1971[b]		0.038	173	53	256

[a] Values of last three quarters of the year only.

[b] Values of first three quarters of the year only.

TABLE A-39. SUMMARY OF QUARTERLY DATA FOR STATION RT 6-21, UPPER KITTLE RUN

	Flow in cfs				pH Value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	1.17	0.17	0.06	0.03	2.5	2.5	2.4	2.5
1966	0.78	1.36	0.04	0.04	2.5	2.5	2.5	2.6
1967	1.84	0.70	0.42	0.44	2.6	2.5	2.7	2.7
1968	0.72	0.96	0.18	0.99	2.7	2.8	2.7	2.8
1969	0.91	0.55	0.33	0.61	2.7	2.6	2.5	2.6
1970	0.81	0.48	0.20	0.51	2.6	2.7	2.5	2.7
1971	1.40	0.81	0.10	0.71	2.8	2.6	2.6	2.6
	Specific Conductance in μmhos/cm							
1965	2,367	2,378	2,751	2,417				
1966	2,602	2,667	2,698	2,099				
1967	2,166	2,153	1,881	1,715				
1968	1,655	1,435	2,233	1,516				
1969	1,633	1,966	1,858	1,813				
1970	1,636	1,633	2,183	1,600				
1971	933	1,780	1,783	1,700				
	Acidity							
	Load in Tons				Concentration in mg/l			
1965	435	218	21	10	1,520	1,253	1,433	1,439
1966	338	541	12	99	1,762	1,618	1,262	906
1967	559	218	90	133	1,242	1,273	865	1,217
1968	183	223	64	260	1,036	944	1,458	1,067
1969	260	175	74	177	1,161	1,298	909	1,195
1970	164	99	58	137	823	833	1,174	1,100
1971	143	168	366	137	569	853	719	796
	Total Iron							
	Load in Tons				Concentration in mg/l			
1965	96	47	4	4	335	268	276	298
1966	81	121	2	22	435	361	230	210
1967	150	54	25	46	333	316	235	423
1968	56	59	16	74	318	248	363	304
1969	79	53	19	61	352	393	235	408
1970	43	25	16	59	216	208	332	473
1971	61	42	92	41	180	218	181	241

(continued)

TABLE A-39 (continued).

	Sulfate							
	Load in Tons				Concentration in mg/l			
Quarter Year	1	2	3	4	1	2	3	4
1965	531	282	25	11	1,858	1,625	1,721	1,505
1966	341	619	15	114	1,780	1,851	1,520	1,102
1967	605	220	109	158	1,344	1,283	1,050	1,445
1968	207	214	65	279	1,172	907	1,475	1,147
1969	294	174	100	214	1,313	1,292	1,222	1,440
1970	236	146	101	202	1,187	1,235	2,035	1,620
1971	239	215	319	192	706	1,094	626	1,117
	Hardness							
	Load in Tons				Concentration in mg/l			
1965	115	70	8	4	391	400	521	488
1966	82	128	5	46	426	381	457	441
1967	152	58	35	43	338	337	331	391
1968	59	78	21	110	337	329	478	450
1969	112	74	38	83	499	548	466	557
1970	83	54	30	82	419	458	604	657
1971	113	72	347	75	332	370	683	433
	Calcium							
	Load in Tons				Concentration in mg/l			
1965	-	49	5	2	-	284	322	315
1966	50	81	3	25	258	241	266	238
1967	89	36	20	26	198	210	194	242
1968	37	48	13	66	209	203	303	272
1969	72	50	29	47	320	368	290	317
1970	49	28	19	47	245	238	392	375
1971	67	49	105	45	198	250	207	260
	Aluminum							
	Load in Tons				Concentration in mg/l			
1965	-	15	1	1	-	87	77	78
1966	12	23	1	4	65	68	64	39
1967	29	11	4	22	63	64	39	203
1968	8	16	4	16	45	67	97	67
1969	15	11	5	13	65	83	57	85
1970	11	5	4	11	57	38	76	86
1971	13	10	51	10	40	49	100	62

TABLE A-40. SUMMARY OF QUARTERLY DATA FOR STATION RT 6-9, DEEP MINE DISCHARGE

Quarter	Flow in cfs				pH Value			
	1	2	3	4	1	2	3	4
Year								
1965	-	0.092	0.019	0.013	-	2.4	2.4	2.3
1966	0.037	0.032	0.019	0.042	2.2	2.3	2.3	2.3
1967	-	-	-	-	-	-	-	-
1968	0.329	0.216	0.046	0.113	2.6	2.6	2.5	2.4
1969	0.169	0.155	0.119	0.166	2.5	2.5	2.4	2.5
1970	0.224	0.163	0.055	0.058	2.4	2.5	2.5	2.5
1971	0.28	0.18	0.18	-	2.6	2.6	2.6	-
	Specific Conductance in μmhos/cm							
1965	-	3,125	3,530	3,290				
1966	3,710	3,186	3,865	3,942				
1967	-	-	-	-				
1968	2,166	2,243	2,683	2,553				
1969	2,266	2,400	2,450	2,600				
1970	2,533	2,116	2,550	2,300				
1971	1,566	1,980	2,066	-				
	Acidity							
	Load in Tons				Concentration in mg/l			
1965	-	37	9	7	-	1,617	1,842	2,043
1966	20	14	10	21	2,133	1,773	2,125	1,960
1967	-	-	-	-	-	-	-	-
1968	116	77	19	53	1,433	1,450	1,680	1,901
1969	67	56	50	70	1,610	1,465	1,700	1,715
1970	84	48	24	25	1,523	1,204	1,768	1,715
1971	76	52	45	-	1,125	1,194	1,052	-
	Total Iron							
	Load in Tons				Concentration in mg/l			
1965	-	9	2	2	-	402	452	517
1966	5	3	3	4	503	407	535	415
1967	-	-	-	-	-	-	-	-
1968	33	16	5	15	413	302	402	532
1969	18	17	12	22	435	447	415	527
1970	20	12	8	8	363	310	565	586
1971	24	14	15	-	355	330	346	-

(continued)

TABLE A-40 (continued).

	Sulfate							
	Load in Tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	-	41	11	8	-	1,805	2,298	2,563
1966	27	25	12	29	2,890	3,237	2,445	2,265
1967	-	-	-	-	-	-	-	-
1968	113	68	17	51	1,393	1,283	1,465	1,837
1969	71	57	45	78	1,697	1,497	1,535	1,920
1970	81	66	35	34	1,477	1,655	2,568	2,380
1971	106	98	52		1,575	2,250	1,186	-
	Hardness							
	Load in Tons				Concentration in mg/l			
1965	-	9	2	1	-	393	430	416
1966	4	3	2	-	394	336	418	-
1967	-	-	-	-	-	-	-	-
1968	29	19	5	14	361	356	393	498
1969	22	23	14	23	521	592	481	567
1970	29	23	8	11	523	573	572	760
1971	35	20	31	-	522	459	716	-
	Calcium							
	Load in Tons				Concentration in mg/l			
1965	-	5	1	1	-	205	396	301
1966	2	2	1	-	264	237	280	-
1967	-	-	-	-	-	-	-	-
1968	19	12	3	9	231	228	273	327
1969	14	14	9	13	330	367	305	313
1970	17	11	5	7	317	372	365	452
1971	21	14	12	-	315	330	276	-
	Aluminum							
	Load in Tons				Concentration in mg/l			
1965	-	2	1	0.3	-	110	119	99
1966	1	1	0.3	1	79	66	57	92
1967	-	-	-	-	-	-	-	-
1968	5	5	1	3	56	90	106	110
1969	4	4	3	5	85	101	90	113
1970	6	2	2	2	109	52	118	140
1971	5	3	6	-	79	75	140	-

TABLE A-41. SUMMARY OF QUARTERLY DATA FOR STATION RT 6-23, DEEP MINE DISCHARGE

Quarter	Flow in cfs				pH Value			
Year	1	2	3	4	1	2	3	4
1965	0	0.69	0.05	0.02	-	2.5	2.5	2.5
1966	0.16	0.12	0.04	0.32	2.4	2.5	2.5	2.5
1967	-	-	-	0.19	-	-	-	-
1968	0.26	0.23	0.13	0.10	2.7	2.7	2.6	2.6
1969	0.16	0.17	0.11	0.17	2.6	2.5	2.4	2.6
1970	0.22	0.17	0.07	0.16	2.5	2.5	2.5	2.6
1971	0.22	0.16	0.25	0	2.7	2.6	2.5	-

	Specific conductance in μmhos/cm			
1965	-	2,485	2,821	3,080
1966	3,218	2,583	3,125	2,490
1967	-	-	-	2,321
1968	2,105	1,841	2,500	1,858
1969	1,866	2,216	2,191	2,070
1970	2,016	2,050	2,283	1,808
1971	1,233	1,840	2,566	-

	Acidity							
	Load in Tons				Concentration in mg/l			
1965	-	276	22	4	-	1,637	1,850	2,337
1966	90	50	18	112	2,275	1,783	2,065	1,428
1967	-	-	-	73	-	-	-	1,560
1968	89	69	54	32	1,407	1,244	1,637	1,317
1969	50	53	33	63	1,281	1,255	1,187	1,450
1970	62	48	25	51	1,183	1,136	1,395	1,267
1971	48	48	77	-	895	1,021	1,266	-

	Total Iron							
	Load in Tons				Concentration in mg/l			
1965	-	60	5	4	-	357	453	610
1966	22	11	4	24	553	400	485	300
1967	-	-	-	19	-	-	-	418
1968	24	19	11	18	375	343	350	359
1969	14	19	7	20	365	447	282	462
1970	13	12	7	19	255	298	428	458
1971	14	10	22		260	258	356	-

(continued)

TABLE A-41 (continued).

	Sulfate							
	Load in Tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	-	331	29	19	-	1,967	2,503	3,210
1966	119	45	19	121	3,013	1,583	2,245	1,545
1967	-	-	-	82	-	-	-	1,770
1968	104	73	51	37	1,653	1,313	1,550	1,552
1969	54	67	40	81	1,400	1,576	1,462	1,890
1970	62	73	38	75	1,185	1,818	2,100	1,851
1971	64	53	73	-	1,195	1,354	1,200	-
	Hardness							
	Load in Tons				Concentration in mg/l			
1965	-	74	8	4	-	438	657	704
1966	23	40	5	164	579	1,411	570	2,090
1967	-	-	-	23	-	-	-	501
1968	28	24	17	13	473	430	515	546
1969	20	26	16	27	524	630	553	615
1970	27	18	11	29	521	460	657	708
1971	23	16	44	-	438	418	733	-
	Calcium							
	Load in Tons				Concentration in mg/l			
1965	-	40	5	3	-	239	435	483
1966	14	8	3	-	343	277	370	-
1967	-	-	-	15	-	-	-	326
1968	18	15	11	8	292	268	351	343
1969	13	18	10	15	335	427	352	352
1970	16	13	8	15	305	320	440	430
1971	14	11	21	-	263	290	346	-
	Aluminum							
	Load in Tons				Concentration in mg/l			
1965	-	9	1	1	-	110	127	137
1966	3	2	1	6	81	65	95	74
1967	-	-	-	2	-	-	-	47
1968	4	4	3	2	61	68	103	101
1969	3	3	2	5	69	86	76	113
1970	5	1	1	3	98	36	98	93
1971	3	2	7	-	59	57	120	

hollows to allow proper drainage during surface reclamation. A considerable difference between the contracted and actual yardage moved was due to modification of the contract in 1967. Subareas 10D, F, H, I, J, K, M, and N were not completed as originally planned. In fact, many of these subareas required additional grading by bulldozer and road grader before they could be planted with grass and trees under the revegetation contract.

Plans to line the established stream channels for a distance of 500 feet with a concrete liner to prevent water from infiltrating into the underground mine were abandoned because of contract modifications.

Clay was compacted against six mine openings that had fractured overburdens. These openings were considered to be dangerous and impractical for installing masonry seals. Four dry masonry walls were installed in the mine portals to form an air seal and to divert water to other openings in which wet seals were installed. It was necessary to excavate approximately 276 cubic yards of material on the outside of the portals and 233 cubic yards of material on the inside before the seals could be constructed. Two dry masonry seals were built in the main headings of old Proudfoot mine at the entrance to Work Area 10 (Subarea A). Two subsidence holes developed because of improper backfilling of the area in front of the seals. This was a result of the contract modification.

Three masonry wet seals were constructed. One is located at the mouth of the Upper Kittle Run subwatershed (RT6-25) and the other two are installed at the head of two hollows (RT6-9 and R6-23). The mine portals were shored with creosote-treated timbers prior to installation of masonry seals. The seals were treated with either bitumastic coating or urethane foam to protect the blocks from acid attack.

In Subareas 10 A - F (Figure A-13) a contour backfill was established by reducing the fractured highwall and moving soil from the center of the hollow. Clay-compacted backfill was done on Subareas A-1, B-1, and C-1 to seal one deep mine opening and fractures in the highwall. Two dry seals were constructed in the easterly portion of the subarea to act as an air seal in the mine. Before a contour backfill could be established, it was necessary to remove a garbage dump. The material was buried in the outer slope of the backfill. In Subarea 10E an old abandoned shaft was uncovered to provide additional access to the three hallways below. The construction of two dry and one wet seal was proposed to act as an air seal. The proposal was not approved and the shaft was again sealed off. The other shaft was not disturbed; it was used to obtain water samples from RT6-26.

In Subarea 10F, a contour backfill was established but was modified considerably because of termination of the contract. A portion of the highwall adjacent to Subarea 10MF was used as a clay borrow pit.

In Subarea 10MG, a masonry wet seal was placed in the main heading to allow drainage of mine water that had originated in the Flatbush watershed.

Four clay seals were placed in Subareas 10H and I to divert water to the wet seal at Station RT6-23. A contour backfill completed the work in this area. A mine opening in Subarea 10-O was sealed by normal pasture backfill.

In Subareas 10ML and M, a pasture backfill was used to complete surface reclamation since there was minimum fracturing in the highwall.

In Subarea 10N a clay seal was constructed, with a pasture backfill completing the reclamation. Originally, plans were made to construct a wet seal, which was instead constructed at a low point in the mine in Subarea 10-0. One wet seal and one dry masonry seal was placed in the portal at RT6-25. These seals were treated with urethane foam to protect the block from acid attack and also to relieve the block walls of any bearing pressure from the roof.

The swampy area in Subarea 10R was not completely drained because of the contract modifications. A drainage channel was established above the swampy area in the left fork of Upper Kittle Run, but the entire channel was not completed as originally planned.

Revegetation of Work Area 10 was completed in May 1968. Table A-42 shows grass and tree species and methods of application. Total area revegetated was 140.3 acres.

TABLE A-42. TYPES OF GRASSES AND TREES
PLANTED AND METHODS OF APPLICATION

Revegetation	Acres	Grasses	lb/acre	Trees[a]
Grass only	17.3	Lespedeza	10	Black alder
Trees only	8.3	Love grass	5	Tulip poplar
Grass and trees	115.0	Ky. bluegrass	5	Cottonwood
Hydromulch	28.1	Tall fescue	5	White oak
		Per. rye grass	10	

[a] Species Applied - Six rows of black alder followed by four rows of tulip poplar followed by two rows of white oak and cottonwood mixture. 890 trees/acre applied.

Prior to planting, lime was applied to the entire area at an average rate of 2.4 tons/acre. Lime requirements were determined by soil samples (two samples/acre), which were analyzed for total acidity based on a potassium chloride extract.

Hydroseeding was accomplished by mixing grass seed, fertilizer (0.43 ton/acre) and metroganic mulch (1 ton/acre) with water and discharging it under high pressure through a nozzle. All areas immediately adjacent to a waterway or stream were hydroseeded. Grasses on the areas eventually died off. Hydroseeding and trees were also applied in Subareas 10A, H, I, J, and M. Hydroseeding only was completed in Subarea 10R, a swampy site at the mouth of the hollow. Grasses have stabilized the area; S. lespedeza, tall fescue, and rye grass are the predominant species.

Only trees were planted on Subareas 10F and H. Nearly all of the trees have died in Subarea 10F. Black alder and cottonwood have grown fairly well in 10H, with more than 50 percent survival of each species. Grass and trees were planted on all steep slopes that were hydroseeded. Some trees were planted with conventional grass planting in Subareas 10B-D, K, L, O, P and Q.

Love grass was still the predominant plant in Subarea 10A for the first two years. Survival of love grass and tall fescue has been good, with over 50 percent cover on most areas. In 1971, the predominant grass in most of the subareas was Serecia lespedeza. This legume has been especially successful where there is little or no competition from other grasses.

An evaluation of the area in 1976 revealed that S. lespedeza and tall fescue had outstanding growth on all areas except extremely acid spots. Black alder trees have variable survival (20 to 30 percent) with the average being 50 percent. Most trees were 5 to 8 feet tall. Trees on the northeast slope were more vigorous then those on the southwest. Survival was poor for white oak, cottonwood, and yellow poplar.

Cost of Work

Records were kept of equipment and labor used in each work area. These data were used to determine the direct cost as reported in Table A-43. The remaining costs were distributed on a direct-cost percentage basis to the work areas. For clearing and grubbing, reclamation and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total cost for each work area is reported in Table A-44.

TABLE A-43. COST OF WORK - DIRECT COST (DOLLARS)[a]

Area No.	Cleaning and grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment and materials	Labor	
10	5,502	21,113	118,092	30,669	10,843	11,840	16,916	7,681	222,656

[a] For cleaning & grubbing, Reclamation and Underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G&A, etc. Revegetation Cost includes cost of labor, equipment & materials.

TABLE A-44. TOTAL COST FOR WORK AREA 10 IN UPPER KITTLE RUN (DOLLARS)

Area No.	Cleaning and grubbing, reclamation, underground	Revegetation	Total	Cost/acre
10	257,033	30,510	287,543	2,049

The high cost per acre, $2,049, is attributed to extensive surface mining on both sides of the hollow and deposition of spoil in the center of the hollow, blocking the normal stream channel. Costs of developing a new drainage channel were extremely high.

Results of Reclamation

The reclamation work has effected a definite improvement in water quality (Figure A-14). Even though the deep mine discharges have increased and the new channel for Kittle Run prevented partial drainage into the underground workings, the concentrations and total load of acidity, iron, and sulfate have decreased. For 1970, the acidity, iron and sulfate concentrations were 983 mg/l, 307 mg/l, and 1,519 mg/l respectively at Station RT 6-21. Values for 1971 were 734 mg/l, 205 mg/l and 886 mg/l. In 1970, the two deep mine discharges contributed nearly half the total flow of the watershed. The concentration of pollutants in the discharges is lower, but in the case of Station RT 6-9, the postreclamation load is 2 to 3 times the 1966 value. Subtracting the deep mine contribution does, however, indicate a sizeable decrease in the pollutants from the strip mine. Surface contributions of acidity for the years 1968, 1969, and 1970 were 221 tons, 244 tons, and 91 tons respectively, as compared to the 1966 value of 655 tons. The combined total loads of acidity, iron, and sulfate for the year 1970 were 458 tons, 143 tons, and 685 tons. These may be compared to the 1966 values of 990 tons, 226 tons, and 1,089 tons.

The load values for 1971 were much larger than for 1970. This was the result of the extremely high flow, especially in September. The concentration of pollutants was lower, but the total yearly flow was more than twice that of 1970.

KITTLE RUN WATERSHED (RT6-1)

Area Description

The complete Kittle Run watershed consists of 874 acres, including the upper Kittle Run basin, which accounts for nearly half the area (Figure A-15). The watershed is oblong, 1.8 miles by 1.1 miles. Kittle Run is 1.7 miles long, falling at an average rate of 0.015 ft/ft from its headwaters. Kittle Run flows into Roaring Creek at Coalton, at Station RT6-1. The highest elevation in the watershed, 2,470 feet, is located in the upper portion (see the Upper Kittle Run segment of Appendix A).

Mining Summary and Work Area Description

The 108 acres of strip mines represents 12 percent of the land area. There were 29,900 feet of highwall exposed in the

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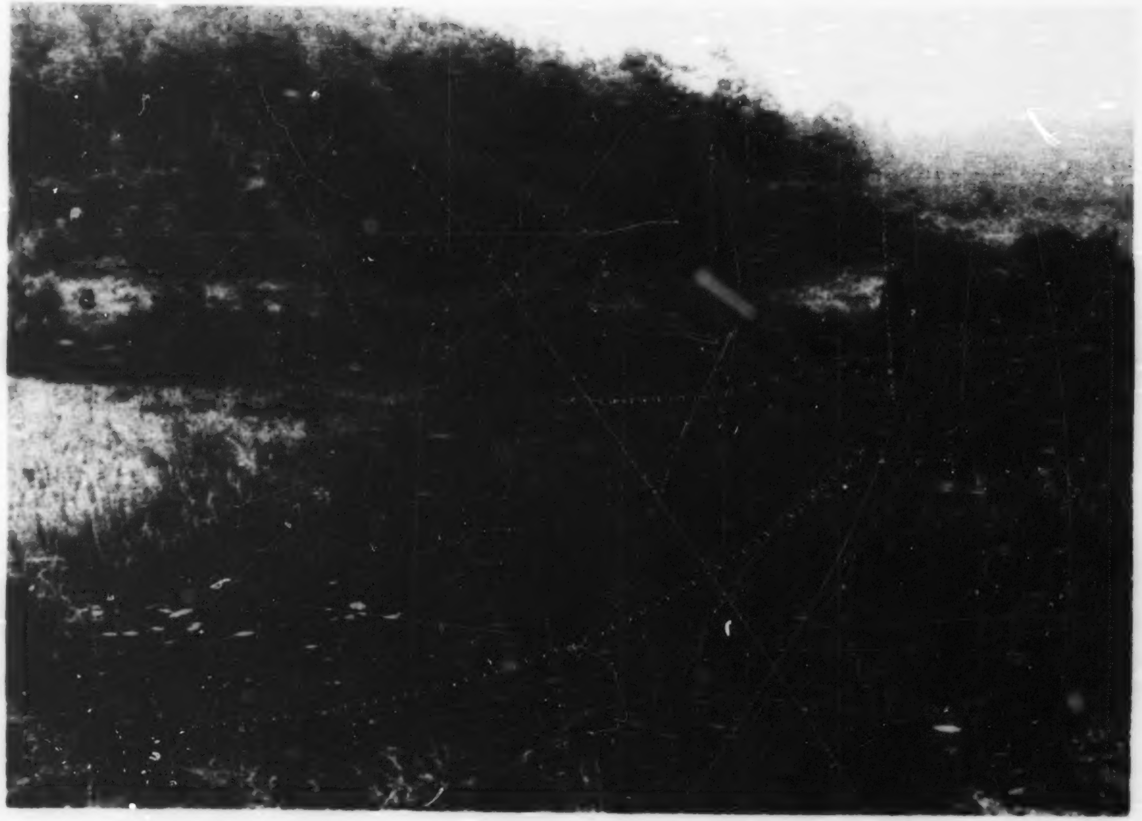

Figure A-14. Work Area 10, summer of 1976.

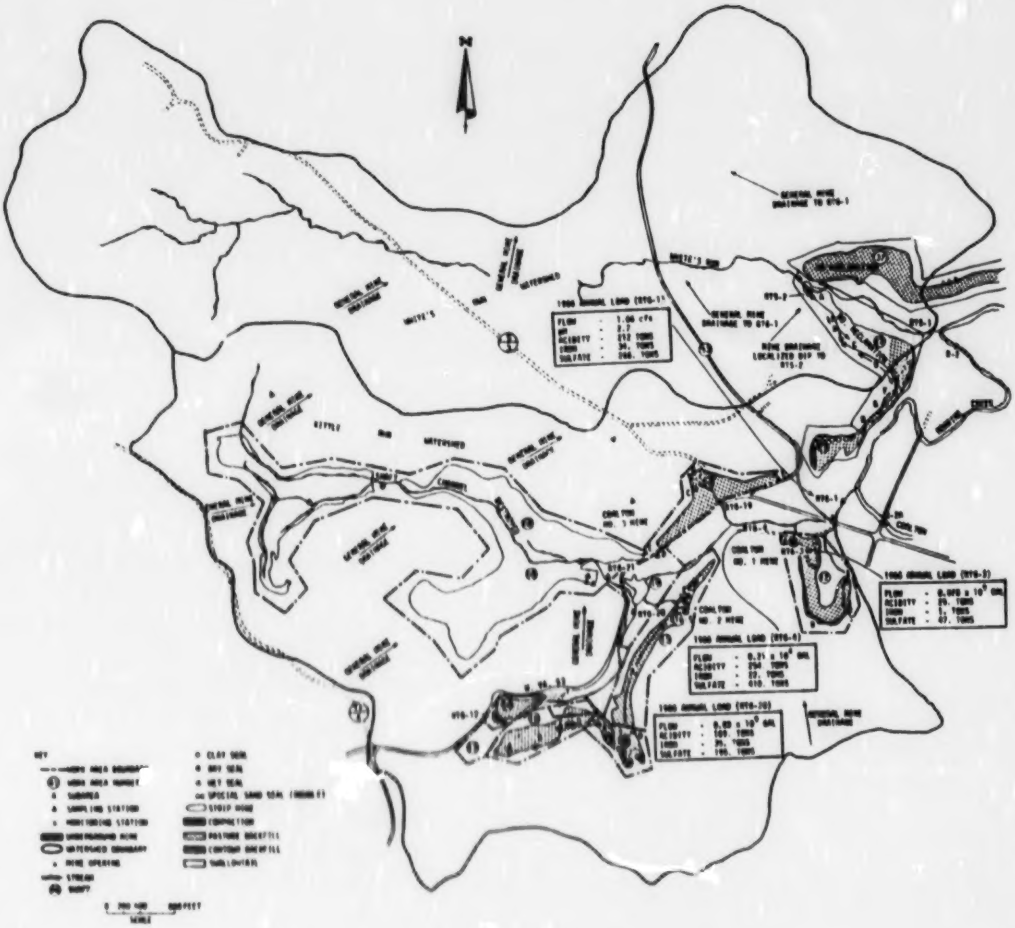
GENERAL MINE DRAINAGE TO RT6-1
WHITE'S RUN
RT6-2
RT6-1
MINE DRAINAGE LOCALIZED DIP TO RT6-2
FLOW : 1.06 cfs
ACIDITY : 212 TONS
IRON : 34. TONS
SULFATE : 266. TONS
KITTLE RUN WATERSHED
COALTON NO. 1 MINE
COALTON NO. 2 MINE
COALTON
RT6-19
RT6-3
RT6-21
RT6-20
GENERAL MINE DRAINAGE
KEY
CLAY SEAL
DRY SEAL
WET SEAL
SAMPLING STATION
MONITORING STATION
WATERSHED BOUNDARY
MINE OPENING
STREAM
SHAFT
STRIP MINE
COMPACTION
CONTOUR BACKFILL
SCALE

Figure A-15. Kittle Run (RT6-1), Lower Roaring Creek (R-2 to R-2A), and Whites Run (RT5-1) watersheds.

surface work, and as in the upper portions, the watershed has been extensively deep mined.

A description of Work Area 10 and the upper half of the watershed were considered earlier. The other work areas are described below.

Work Area 12 - Coalton School strip (7.5 acres)--

Subarea A--A caved portal, 16 feet wide, with no drainage. This was the Coalton No. 1 portal (RT6-2). Mean yearly discharge for 1966 was 0.12 cfs, pH - 2.9, acidity - 219 mg/l, and iron concentration - 7.6 mg/l.

Subarea B--A concealed opening in the highwall with little discharge.

Subarea C--A concealed opening in the highwall with a slight seepage.

Work Area 13 - Coalton No. 2 Strip--

Subarea A--A 1,200-foot strip with at least 13 concealed openings.

Subarea B--A drainage entry with a yearly discharge of about 0.89 cfs in 1966 (RT6-5), pH - 2.8, acidity - 304 mg/l and iron - 26 mg/l.

Subarea C--Three concealed openings in the highwall.

Subarea D--A concealed opening.

Subarea E--A concealed portal.

Subarea F--A 16-foot portal in fair condition (RT6-4). Mean yearly flow rate in 1965 was 0.024 cfs, pH - 3.0, acidity - 191 mg/l, and iron - 58 mg/l.

Work Area 14 - Coalton No. 2 Strip--

Subarea A--Three concealed openings in the highwall.

Subarea B--A 16-foot opening in the highwall with a slight discharge.

Subarea C--A caved and partially concealed opening.

Work Area 15--

Subarea A--A 4-inch pipe and a 2-inch pipe have been driven through the highwall into the deep mine.

Subarea B--A 5-foot corrugated steel pipe escapeway through the highwall into the mine. No drainage was evident.

Subarea C--A 16-foot portal (RT6-6A) filled with debris. Mean yearly flow in 1966 was 0.032 cfs, pH - 2.8, acidity - 262 mg/l, and iron - 23 mg/l.

Work Area 16--
A large coal refuse pile adjacent to tipple.

Work Area 17--
A large subsidence area between strips 18 and 15.

Work Area 18 - Coalton Curve Strip (1 acre)--
A 200-foot strip leveled and planted in pines. Mean yearly discharge for 1966 was 0.13 cfs from a flooded deep mine opening (RT6-12), acidity - 941 mg/l and iron - 217 mg/l, respectively.

Work Area 19 - Coalton Swamp--
A large acid-water swamp with refuse piles around the perimeter.

Work Area 20 - Proudfoot Strip (8 acres)--

Subarea A--Area of limited subsidence.

Subarea B--Area of limited subsidence.

Subarea C--A partly concealed mine opening.

Subarea D--Coalton No. 3 portal. There was drainage from the portal, but some water discharged into the abandoned workings.

Subarea E--A portal for Proudfoot Mine.

Description of Mine Drainage Problem

The lower section of the basin was greatly affected by deep mine drainage. Subtracting the contribution of RT6-21 from RT6-1 approximates the drainage characteristics of Lower Kittle Run (Table A-45). For the prereclamation years of 1965 and 1966, the deep mine discharges at RT6-3, RT6-5, and RT6-20 showed a total yearly flow average of 0.325 billion gallons of water with 405 tons of acidity, 49 tons of iron, and 466 tons of sulfate (Table A-46). This deep mine discharge was equal to or

TABLE A-45. SUMMARY OF ANNUAL DATA FOR STATION RT 6-1, MOUTH OF KITTLE RUN, AND STATION RT 6-1 MINUS RT 6-21, LOWER KITTLE RUN

Year	Rainfall, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station RT 6-1					
Before reclamation					
1965	37.77	0.49	943	167	1,449
1966	47.14	0.39	847	136	1,064
After reclamation					
1968	41.46	0.75	1,343	296	1,957
1969	42.58	0.53	1,058	255	1,435
1970	42.60	0.36	633	143	1,048
1971	87.72	0.92	1,359	303	1,999
Station RT 6-1 Minus Station RT 6-21					
Before reclamation					
1965		0.374	259	18	600
1966		0.237	-143	-90	-25
After reclamation					
1968		0.582	613	91	1,192
1969		0.388	372	43	553
1970		0.242	175	0.0	363
1971		0.624	495	67	1,034

TABLE A-46. SUMMARY OF ANNUAL DATA FOR STATIONS RT 6-3, RT 6-5 AND RT 6-20, UNDERGROUND MINE DISCHARGES

Year	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station RT 6-3				
Before reclamation				
1965	-	-	-	-
1966	0.028	25	1	47
After reclamation				
1968	0.028	25	1	47
1969	0.038	29	0.8	57
1970	0.030	25	0.6	45
1971[a]	0.037	17	0.4	28
Station RT 6-4				
Before reclamation				
1965	0.232	219	17	427
1966	0.210	254	22	410
After reclamation				
1968	0.185	159	12	322
1969	0.190	178	14	338
1970	0.125	116	11	281
1971[a]	0.206	119	9	184
Station RT 6-20				
Before reclamation				
1965	0.07	113	21	152
1966	0.08	169	35	195
After reclamation				
1968	0.097	17	57	253
1969	0.061	199	62	228
1970	0.086	211	76	329
1971[a]	0.200	381	106	373

[a] Data for first 9 months of the year only.

greater than the measured discharge for Lower Kittle Run in 1965 at RT6-1. This was a result of mine water going into storage in a swamp in Work Area 19. In 1966, deep mine discharges contributed more than 90 percent of the flow in Kittle Run (for quarterly data for Station RT6-1, see Table A-47).

Reclamation Work Performed

All disturbed land in the Kittle Run watershed was reclaimed, with the exception of Work Areas 12 and 20. These work areas were not completed as originally planned because of contract modifications.

A new channel, 2,000 feet long, was constructed from Work Area 19 to Station RT6-1. The Kittle Run swamp was then allowed to drain so that Work Area 19 could be reshaped. Since the highwall was highly fractured in Work Areas 12-15, it was necessary to reduce it and construct a contour backfill. Actual yardage moved during construction was not computed except for that in Work Area 18.

Work Area 12 - Coalton School Strip (7.5 acres)--

Work Area 12 was heavily subsided, with large boulders and rocks in the outcrop and spoil areas. This material was eventually buried and covered with unconsolidated material. A contour backfill was constructed by reducing a portion of the highwall. During construction, interception of an old drainway (RT6-2A) caused a temporary flood in the vicinity of the Coalton High School below. A wet seal with four 4-inch plastic drain pipes was placed in the hole and a wooden shelter constructed over it.

A masonry wet seal was constructed in old Coalton No. 1 portal at RT6-3. The seal was a double-block wall treated with bitumastic material to retard acid attack.

Work Area 12 was revegetated by planting 5 acres of grass and trees on the steep slope with a hydromulcher and 8 acres of grass with conventional farm equipment. Prior to planting, the soil was treated with 2-1/2 tons per acre of lime and 0.85 tons per acre of 10-10-10 fertilizer. A grab mixture of scotch pine, white pine, shortleaf pine, Virginia pine and black alder was planted at a density of 500 trees per acre. The following seeding mixture was applied to the area:

Kentucky bluegrass	8 lb/acre
Birdsfoot trefoil	13 lb/acre
Perennial rye grass	3 lb/acre
Tall fescue	5 lb/acre

Survival of all species planted has been excellent; trefoil, fescue, and rye grass are predominant. Some rill erosion has

TABLE A-47. SUMMARY OF QUARTERLY DATA FOR STATION RT 6-1, MOUTH OF KITTLE RUN

Quarter	Flow in cfs				pH Value			
	1	2	3	4	1	2	3	4
Year								
1965	4.920	2.809	0.368	0.276	2.8	2.7	2.7	2.7
1966	1.802	3.025	0.570	1.242	2.7	2.7	2.7	2.7
1967	8.982	3.218	0.744	3.563	2.8	2.8	2.9	2.9
1968	5.023	4.436	0.533	2.776	2.9	2.9	2.9	2.9
1969	4.005	2.133	1.376	1.476	2.9	2.9	2.7	2.8
1970	2.190	2.199	0.838	0.861	2.8	2.9	2.8	2.9
1971	4.670	2.280	6.050	2.630	3.0	2.9	3.0	2.8
	Specific conductance in μmhos/cm							
1965	1,382	1,309	1,582	1,493				
1966	1,445	1,485	1,589	1,2[illegible]9				
1967	1,238	1,266	1,218	1,153				
1968	1,185	1,125	1,500	1,020				
1969	1,068	1,233	1,200	1,283				
1970	1,131	1,016	1,410	1,056				
1971	750	1,060	1,166	1,233				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	576	291	41	35	477	423	455	516
1966	266	412	66	103	601	555	477	337
1967	864	322	61	401	392	408	332	459
1968	533	459	76	295	432	404	580	433
1969	501	240	125	192	510	458	372	530
1970	246	188	102	97	458	348	496	460
1971	332	196	440	263	293	354	300	412
	Iron							
	Load in tons				Concentration in mg/l			
1965	111	46	5	5	92	66	53	70
1966	44	67	8	17	100	90	57	57
1967	157	57	12	92	71	72	65	106
1968	122	91	13	70	99	84	98	103
1969	111	69	25	50	113	131	74	138
1970	53	34	22	34	98	63	106	162
1971	88	37	90	62	78	67	61	97

occurred on the steeper slopes but the area is fairly well stabilized.

Work Areas 13 and 19 - Coalton No. 2 Strip and Coalton Swamp-- In Work Area 13, a contour backfill was achieved by reducing a portion of the fractured highwall and using this material to complete the backfill. Later, two large subsidence holes developed between the highwall and the backfill. These required additional work. One large subsidence area was reclaimed under the revegetation contract. A clay seal was constructed at 13-F and masonry wet and dry seals were constructed in Old No. 2 Mine Portal at RT6-5. Site preparation required 625 cubic yards of outside excavation and 259 cubic yards of excavation in the portal. In Work Area 19 a drainage channel for Kittle Run was constructed by dynamiting the old channel to allow proper drainage after the swampy area had drained. Only minimal material was moved because of the unstable condition of the marshy area. A good drainage channel was developed.

The following types of grasses and trees were planted on Work Areas 13 and 19:

Grass		Trees	
S. lespedeza	20 lb/acre	Japaneses larch)	
Tall fescue	15 lb/acre	Scotch pine)	Hand planted
Tall oat grass	15 lb/acre	Shortleaf pine)	641 trees/acre
		Virginia pine)	
		White pine)	
		Black locust	- Hydroseeded

Twenty seven of the 42 acres were hydromulched. The mulch included grass seed, fertilizer (1/2 ton/acre), locust seed, and metroganic mulch mixed with water and sprayed on the surface under high pressure. Lime was applied at an average of 2 tons per acre. Except for rill erosion at the bottom of the backfill, revegetation has completely covered the area. The upper and steeper parts of the contour backfill were densely covered with S. lespedeza, fescue, larch and black locust. Hydroseeding unscarified locust seed on this area was highly successful. Larch was a predominant tree in the area.

An evaluation of the area in the summer of 1976 revealed that the survival of white, scotch and Virginia pine was good to excellent and tree height was 8 to 15 feet high. Survival of shortleaf pine was poor. Larch survival was good to excellent and tree height was 10 to 12 feet. Black locust were spotty and 6 to 14 feet tall. In Work Area 19, S. lespedeza growth was outstanding. Tall oat grass and fescue appear to have been crowded out by vigorous growth of S. lespedeza. Oat grass was dominant under pines and locust. Growth of S. lespedeza appeared to have depressed encroachment of hardwood volunteers. There was much weed encroachment on parts of this area.

Work Area 14 - Coalton No. 2 Strip--

A combination contour backfill and pasture backfill was constructed in Work Area 14. A dry masonry seal was placed in Subarea 14A. All other openings were sealed by earthen material during the normal backfilling operation.

Tall fescue (15 lb/acre), tall oat grass (13 lb/acre), *S. lespedeza*, and black locust were hydroseeded on 1.2 acres of the 12.2-acre area. Lime was applied prior to revegetation at the rate of 1/2 ton per acre. Except for stream channel erosion, the surface has been stabilized by grasses and trees. Growth from locust seed applied by the hydroseeder has been successful. *Serecia lespedeza* is the predominant plant in this area.

Work Area 15--

In Work Area 15, a pasture backfill was constructed in Subareas C and D in the vicinity of wet seal RT6-6A. Two dry masonry seals and a wet masonry seal were constructed in the old mine portals. The dry seal acts as an air seal and as a water diversion. Approximately 590 cubic yards of outside earthen material and 188 cubic yards of debris inside the portals were removed before the seals were built. A contour backfill was affected on the remaining part of the area. All concealed openings were sealed with backfill material.

Work Areas 16 and 17--

Reclamation of Roaring Creek in Work Area 16 to allow water to drain was done by dynamiting a 600-foot ditch from Work Area 16 through Work Area 15 to Work Area 18. The remaining portion of Work Area 16 received a pasture backfill which formed both sides of the stream channel. In Work Area 17, subsidence holes were filled and the stream channel was opened for surface drainage above the strip mined area.

Work Area 18 - Coalton Curve Strip (1 acre)--

In Work Area 18, a contour backfill was constructed. In the process of preparing the area for backfilling, a piece of heavy equipment broke through into the deep mine workings. The old workings were cleaned out with a high-lift shovel and clay was compacted into the old mine. These operations required 7,800 cubic yards to fill the subsidence area and 7,400 cubic yards of clay-compacted backfill.

Two dry masonry seals and one wet masonry seal were constructed in the portals at RT6-12. 1,130 cubic yards of earthen material were moved from the entrance of the portals and about 140 cubic yards of unclassified material were removed from the inside of the portal before construction of the seals. About 41 percent more material was required to complete the contour backfill than was originally estimated in the contract (36,000 cubic yards).

The same type of soil treatment and planting was used in Work Areas 15-18. Approximately 2 tons of lime per acre were applied to these areas by conventional methods. Fertilizer (10-10-10) was applied at the rate of 0.7 tons per acre either by hydromulcher or conventional farm equipment. The same type of grasses and trees were planted as in Work Area 13. Grass and trees were planted on 5.2 acres, and 5.2 acres were hydroseeded. Practically all these areas have good vegetative cover, with tall fescue and *S. lespedeza* being the predominant grasses and black locust and Japanese larch the predominant trees. Tree survival is estimated at more than 60 percent in all the areas that were planted. Except for a few sheep pastured in the area in the spring of 1969, no grazing has taken place in the entire Kittle Run watershed.

Cost of Work

Records were kept of equipment and labor in each work area. These data were used to determine the direct cost, as reported in Table A-48. The remaining costs were then distributed on a direct-cost percentage basis to the work areas. For the clearing and grubbing, reclamation, and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total cost for each work area is reported in Table A-49.

High cost per acre in Work Area 20 was caused by the highly fractured highwall; considerable time and equipment were required for completion of the pasture backfill. High equipment costs can also be attributed to long downtime of heavy equipment in the area. High cost per acre in Work Areas 14 - 18 was due to the heavily subsided areas requiring use of equipment over long periods.

Results of Reclamation

The effects of reclamation on water quality in the watershed are slight. Comparison of the 1966 and 1970 values at RT6-1 shows that the iron content has increased slightly and the flow, acidity, and sulfate loads have decreased. In 1971, heavy rains in September account for the high flow and load values. The deep mine loads for the lower basin have shown no particular trends differing from those of the prereclamation year of 1966 (see Table A-46). The total values of flow for the years 1966, 1968, 1969, and 1970 were 0.32, 0.31, 0.29, and 0.24 billion gallons. Acidity loads were 449, 398, 406, and 352 tons for the same years. The positive effects of strip mine reclamation by the year 1970 were overshadowed by the large percentage (86 percent) of the deep mine contribution to the total flow.

TABLE A-48. COST OF WORK - DIRECT COST (DOLLARS)[a]

Area No.	Cleaning and grubbing		Reclamation		Underground		Revegetation		Total
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment and materials	Labor	
12	1,965	2 921	7,441	2,595	2,113	3,704	2,544	569	23,786
13-19	1,918	4,917	25,156	4,580	3,812	3,676	10,073	1,542	55,674
14	2,076	2,741	19,579	2,701	287	558	1,440	558	29,940
15-18	874	2,591	13,527	2,758	5,069	7,232	2,740	678	35,469

[a] For cleaning and grubbing, Reclamation and Underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G & A, etc. Revegetation Cost includes cost of labor, equipment & materials.

TABLE A-49. TOTAL COST FOR WORK AREAS IN LOWER KITTLE RUN (DOLLARS)

No.	Cleaning and grubbing, reclamation, underground	Revegetation	Total	Cost/acre
12	26,829	3,828	30,657	2,358
13-19	57,177	14,133	71,310	1,686
14	36,262	2,473	38,735	3,175
15-18	41,595	4,197	45,792	4,089
20	40,883	1,411	42,294	4,699

LOWER ROARING CREEK (STATIONS R-2A TO R-3)

Area Description

The watershed drains the area of Kittle Run (RT-2 to R-2A) and 54 acres in the vicinity of Coalton (see Figure A-15). It encompasses a total of 928 acres, and the watershed rises from an elevation of 2,150 to 2,470 feet in the upper portion of the Kittle Run watershed.

Mining Summary and Work Area Description

With the exception of the Kittle Run area (RT6-1), only one strip mine, Work Area 21, containing 5.8 acres, is located between Stations R-3 and R-2A. Five caved openings were located on the western side of the strip pit. The underground working was dry and in good condition except for a few local roof falls. Because of lack of backfill material, a pasture backfill was recommended.

Description of Mine Drainage Problem

Station R-2A was used to monitor the quality and quantity of water draining from this area. Station R-3 shows the water quality and flow entering this section of Roaring Creek. These data are presented in Tables A-50 and A-51.

The main contribution to water pollution in this area comes from the Kittle Run watershed (RT6-1), reported earlier in this report. Since there were no significant discharges from the strip mine area, only natural runoff flowed from a small drainage area above the mine. Increases in iron, acidity, and sulfate concentration were attributed to Kittle Run subwatershed. Except for sulfates, no appreciable change in water quality was found for the period of record.

Reclamation Work Performed

Only exploratory work was performed in Work Area 21. All five mine openings were excavated but, owing to contract modifications, these entries were later covered with soil to form a modified swallowtail backfill. Before revegetation, 2 tons per acre of lime and 0.5 tons of 10-10-10 fertilizer per acre were applied. Approximately an acre of disturbed land was revegetated with Kentucky bluegrass (17 lb/acre), perennial rye grass (10 lb/acre), Japanese larch, and black alder (500 trees/acre). Survival of all species has been good. Tree survival is estimated at 75 percent or better.

TABLE A-50. SUMMARY OF ANNUAL DATA FOR STATION R-3 AND STATION R-2A

Year	Flow, cfs	pH	Acidity, tons	Iron, tons	Sulfate, tons
Station R-3					
Before reclamation					
1965	29.6	3.6	920	47	1,850
1966	34.2	3.4	1,810	65	2,800
After reclamation					
1968	42.3	3.8	1,460	52	2,550
1969	33.8	3.9	1,570	53	1,620
1970	37.8	4.0	920	92	1,430
1971	101.3	4.1	4,726	120	3,700

	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Station R-2A				
Before reclamation				
1965	32.0	2,670	281	4,480
1966	38.7	3,520	304	5,110
After reclamation				
1968	45.2	3,180	507	4,990
1969	34.2	2,550	328	3,560
1970	39.9	2,510	334	3,550
1971	-	-	-	-

TABLE A-51. SUMMARY OF QUARTERLY DATA FOR STATION R-2A, LOWER ROARING CREEK

Quarter	Flow in cfs				pH Value			
	1	2	3	4	1	2	3	4
Year								
1965	86.37	36.85	1.52	3.43	3.4	3.1	2.8	3.0
1966	43.83	58.77	9.36	43.00	3.2	3.1	2.8	3.3
1967	128.86	78.10	15.04	48.49	3.4	3.3	3.3	3.4
1968	59.40	77.25	4.37	39.85	3.4	3.6	3.1	3.5
1969	35.70	21.33	46.85	32.92	3.4	3.3	3.2	3.4
1970	73.83	36.83	10.58	38.23	3.4	3.2	3.4	3.6
1971	93.00	28.40	-	-	3.8	3.5	-	-

Specific conductance in μmhos/cm

1965	326	537	1,189	781
1966	399	424	877	294
1967	320	362	449	262
1968	312	268	750	340
1969	356	396	311	333
1970	279	370	455	243
1971	160	286	-	-

Acidity

	Load in tons				Concentration in mg/l			
1965	1,288	1,092	107	180	60	121	286	214
1966	1,036	1,319	510	652	96	91	222	62
1967	1,919	1,347	363	809	61	70	98	68
1968	1,008	1,216	220	736	69	64	205	75
1969	665	517	751	618	76	99	65	77
1970	1,035	721	229	527	57	80	88	56
1971	1,353	400	-	-	60	58	-	-

Iron

	Load in tons				Concentration in mg/l			
1965	140	118	9	14	7	13	25	17
1966	106	121	35	42	10	8	15	4
1967	221	143	41	107	7	7	11	9
1968	148	234	29	96	10	12	28	10
1979	100	68	81	79	11	13	7	10
1970	144	66	29	95	8	7	11	10
1971	113	41	-	-	5	6	-	-

(continued)

TABLE A-51 (continued).

	Sulfate							
	Load in tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	2,165	1,869	181	263	102	207	485	312
1966	1,436	1,914	710	1,053	133	133	309	100
1967	3,278	2,189	645	1,130	104	115	175	95
1968	1,554	1,803	298	1,334	107	95	278	137
1969	1,004	602	1,090	864	115	115	95	107
1970	1,388	905	276	980	77	100	106	105
1971	879	461	-	-	39	67	-	-
	Hardness							
	Load in tons				Concentration in mg/l			
1965	1,069	920	97	130	50	101	259	154
1966	583	941	316	613	54	65	137	58
1967	1,732	951	386	749	56	49	104	63
1968	806	890	153	731	55	47	142	74
1969	668	492	864	603	76	94	75	74
1970	1,071	488	197	725	59	54	75	77
1971	1,038	282	-	-	46	41	-	-
	Calcium							
	Load in tons				Concentration in mg/l			
1965	-	771	59	78	-	85	159	93
1966	362	539	177	359	34	37	77	34
1967	930	523	213	428	29	27	58	36
1968	486	584	100	414	33	31	94	42
1969	428	302	517	351	49	58	45	44
1970	643	388	148	377	36	43	57	40
1971	519	213	-	-	23	31	-	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	107	8	15	-	12	21	18
1966	68	83	37	49	6	6	16	5
1967	161	95	28	59	5	5	7	5
1968	64	88	17	110	4	5	16	11
1969	63	36	73	57	7	7	6	7
1970	83	36	16	59	5	4	6	6
1971	90	21	-	-	4	3	-	-

Cost of Work

Total cost for underground investigation, reclamation, and revegetation was $4,534, as shown on Table A-52. About half the cost was for reclaiming the area for disturbances during underground exploration.

TABLE A-52. RECLAMATION COSTS FOR WORK AREA 21

Direct cost	
Clearing and grubbing	$ 24
Reclamation operation	2,119
Underground	1,116
Revegetation	235
Total	$3,494
Indirect cost	$1,040
Total cost	$4,534

Results of Reclamation

Revegetation has been very successful in this watershed. Water quality, however, has shown no definite improvement as indicated in Table A-50.

WHITE'S RUN WATERSHED (RT 5-1)

Area Description

The White's Run watershed is 2.2 miles long and 0.8 miles wide; the total area is 760 acres. The basin is adjacent to and just north of Kittle Run (see Figure A-15). White's Run flows eastward into Roaring Creek downstream from Coalton. The stream is about 2.15 miles long and is peculiar in that the channel completely disappears at about its midpoint. The water enters a subsidence area and drains into the mine workings below. Approximately 287 acres drain to this area. A quarter mile downstream, the channel forms again and continues to Roaring Creek. The headwaters of White's Run are at elevation 2,320 feet, and the mouth is at 2,140 feet. The average gradient is 0.016 ft/ft. Except for a few houses along Route 53 and in the northwestern corner, the basin is unpopulated.

Mining Summary and Work Area Description

The White's Run basin contained only 19 acres of surface mines, accounting for 2.5 percent of the total area or 4 percent of the area draining to RT 5-1. Nine hundred feet of exposed highwall were left by the mining operation. Two strip mines

(Work Areas 22 and 37) extend in part into the lower end of the watershed.

As with the Kittle Run watershed, deep mining in the area was extensive. The large Norton drift mine (3,000 acres) underlies most of the basin. Although most of the underground mine drains in a northwesterly direction to Station GT6-1, a localized dip near Work Area 22A carries some water to the entry at RT5-2, which has a continual flow of acid water (Table A-53). Quarterly data are presented in Table A-54.

Two work areas are partially included in the basin and they are described below.

Work Area 37 - North White's Run Strip (11 acres)--
Only part of this area lies in this watershed and the remainder lies in the area of the mouth of Roaring Creek which is discussed later.

Work Area 22 - South White's Run Strip (7.7 acres)--
Only part of this area lies in this watershed and the remainder lies in the area of the mouth of Roaring Creek which is discussed later.

Subarea A--A 16-foot partially caved entry discharging (RT 5-2). Average flow - 0.188 cfs, acidity - 844 mg/l, iron - 106 mg/l, pH - 2.7.

Subarea B--Six or more concealed openings along the highwall.

Subarea C--A 16-foot caved opening to the old workings.

Subarea D--Six or more concealed openings along the highwall.

Description of Mine Drainage Problem

Most of the pollution load carried by White's Run is picked up in the lower reaches from the underground mine (RT 5-2) and the strip mine area. In 1966 the upper portion of the stream, above any mining, had a pH value of 5.2 and carried 5.8 mg/l acidity, 0.62 mg/l iron and 9.7 mg/l sulfate (Station RT 5-3). At its mouth, the concentrations were 425 mg/l acidity, 80.5 mg/l iron, and 592 mg/l sulfate, with a pH value of 2.8.

A large and rather consistent contributor to the pollution load is the deep mine discharge at Station RT 5-2. For the base year 1966, RT 5-2 provided 0.047 billion gallons, 11 percent of the total flow. Acidity, iron, and sulfate were carried in concentrations of 844 mg/l, 105 mg/l, and 1,153 mg/l. The total load carried out of the mine was 158 tons of acidity, 32 tons of

TABLE A-53. SUMMARY OF ANNUAL DATA FOR STATION RT5-1, MOUTH OF WHITE'S RUN, AND STATION RT5-2, DEEP MINE DISCHARGE[a]

Year	Rainfall, inches	Flow, billion gallons	Acidity, tons	Iron, tons	Sulfate, tons
Station RT5-1					
Before reclamation					
1965	37.77	0.407	392	90	691
1966	47.14	0.419	649	115	894
After reclamation					
1968	41.46	0.544	463	102	690
1969	42.58	0.342	314	70	426
1970	42.60	0.405	131	34	215
1971	37.92	-	-	-	-
Station RT5-2					
Before reclamation					
1965	-	-	-	-	-
1966		0.047	158	32	212
After reclamation					
1968		0.049	132	42	163
1969[a]		0.025	73	26	83
1970		-	-	-	-
1971		-	-	-	-

[a] First three quarters only. Entrance was bulkhead-sealed September 1969.

TABLE A-54. SUMMARY OF QUARTERLY DATA FOR STATION RT5-1, MOUTH OF WHITE'S RUN

	Flow in cfs				pH value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	5.01	1.66	0.11	0.13	3.1	2.9	2.7	2.7
1966	1.56	2.81	0.21	2.53	2.9	2.8	2.7	2.8
1967	4.28	3.79	0.98	1.71	2.8	2.9	2.9	3.1
1968	2.37	3.95	0.39	2.52	3.0	3.2	2.9	3.1
1969	1.76	1.53	1.48	0.93[a]	3.1	3.0	3.1	4.2[a]
1970	2.88	1.74	0.79	1.47	4.2	3.9	3.8	5.2
1971	4.00	0.65	5.21	-	5.0	5.8	5.8	-
	Specific conductance, μmhos/cm							
1965	799	1,091	1,784	1,569				
1966	875	1,059	1,904	1,423				
1967	1,003	858	1,452	461				
1968	765	500	1,148	591				
1969	636	856	648	431[a]				
1970	268	430	728	115				
1971	128	186	145	-				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	225	131	16	20	183	322	594	609
1966	96	223	34	296	252	324	648	476
1967	368	217	121	51	351	234	502	121
1968	151	142	39	131	259	147	408	212
1969	103	140	63	8[a]	239	371	175	35[a]
1970	39	47	36	9	55	109	187	25
1971	5	3	0	-	5	20	0	-
	Iron							
	Load in tons				Concentration in mg/l			
1965	224	107	13	13	182	262	505	401
1966	69	142	24	210	181	206	460	338
1967	157	120	80	41	150	128	330	98
1968	71	84	22	99	122	86	227	161
1969	76	85	73	39[a]	174	226	201	171[a]
1970	38	6	18	21	54	13	93	59
1971	31	1	-	-	32	12	-	-

(continued)

TABLE A-54 (continued).

Quarter	Sulfate							
	Load in Tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
1965	413	225	26	27	336	552	999	844
1966	146	301	48	399	383	436	906	642
1967	489	320	176	81	466	344	731	193
1968	227	201	49	213	391	208	505	345
1969	143	148	106	29[a]	331	393	292	127[a]
1970	53	83	31	48	75	195	161	132
1971	18	7	-	-	15	42	-	-
	Hardness							
	Load in Tons				Concentration in mg/l			
1965	224	107	13	13	182	262	505	401
1966	69	142	24	210	181	206	460	338
1967	157	120	80	41	150	128	330	98
1968	71	84	22	99	122	86	227	161
1969	76	85	73	39[a]	174	226	201	171[a]
1970	38	6	18	21	54	13	93	59
1971	31	1	-	-	32	12	-	-
	Calcium							
	Load in Tons				Concentration in mg/l			
1965	-	96	9	10	-	236	339	293
1966	49	96	16	135	127	140	312	216
1967	96	73	80	23	92	79	210	55
1968	45	55	15	63	78	57	151	102
1969	50	56	46	26[a]	116	148	128	114[a]
1970	26	38	18	10	37	89	91	29
1971	16	6	-	-	17	39	-	-
	Aluminum							
	Load in Tons				Concentration in mg/l			
1965	-	8	1	1	-	21	26	24
1966	4	8	1	9	11	11	26	14
1967	16	10	7	4	16	11	31	9
1968	7	6	2	10	12	6	19	16
1969	5	6	3	1[a]	12	16	8	5[a]
1970	5	0.5	1	0.5	7	1	8	1
1971	2	0.2	-	-	2	1	-	-

[a] Bulkhead mine seal in place.

iron and 212 tons of sulfate. As shown in Table A-53, these quantities amounted to 24 percent, 28 percent, and 24 percent of the total load for each pollutant respectively.

Reclamation Work Performed

The work performed in the various work areas within this watershed is described below.

Work Area 37 - North White's Run Strip (11 acres)--
Because the project was terminated, no work was performed in the portion of Work Area 37 in the White's Run watershed.

Work Area 22 - South White's Run Strip (7.7 acres)--
No surface mine reclamation was performed in this area. Four seals were constructed at Subarea 22A. Two dry seals and a clay seal were constructed to force water out the wet seal at Station RT 5-2. To the west of RT 5-2 another portal was present that contained a WPA air seal (it was discovered later that this seal had been breached). The four seals required 236 cubic yards of outside excavation and 39 cubic yards inside. At a later date new experimental type seals were constructed (see Special Studies section). Following construction of the seals, some cleanup work was performed in the area.

Cost of Work

The direct cost of building the seals was $2,652. Total cost including indirect cost was $3,442.

Results of Reclamation

Since a special mine sealing program was undertaken in 1969, only the data through 1968 are comparable to the data for prereclamation years. The data in Table A-53 indicate that no definite improvement occurred. This conclusion was further verified by the deep mine discharge.

MOUTH OF ROARING CREEK (R-2A TO R-1)

Area Description

The watershed contributing to Roaring Creek between R-2A and R-1 contains 4,612 acres, including the White's Run drainage basin (Figure A-16). Most of the land lies to the east of the creek. The length of the stream between R-2A and R-1 is 3.66 miles. Elevation of the watershed ranges from 1,864 feet at the mouth of Roaring Creek to 3,400 feet along the eastern divide. This last reach of Roaring Creek falls 279 feet for an average descent of 0.014 ft/ft.

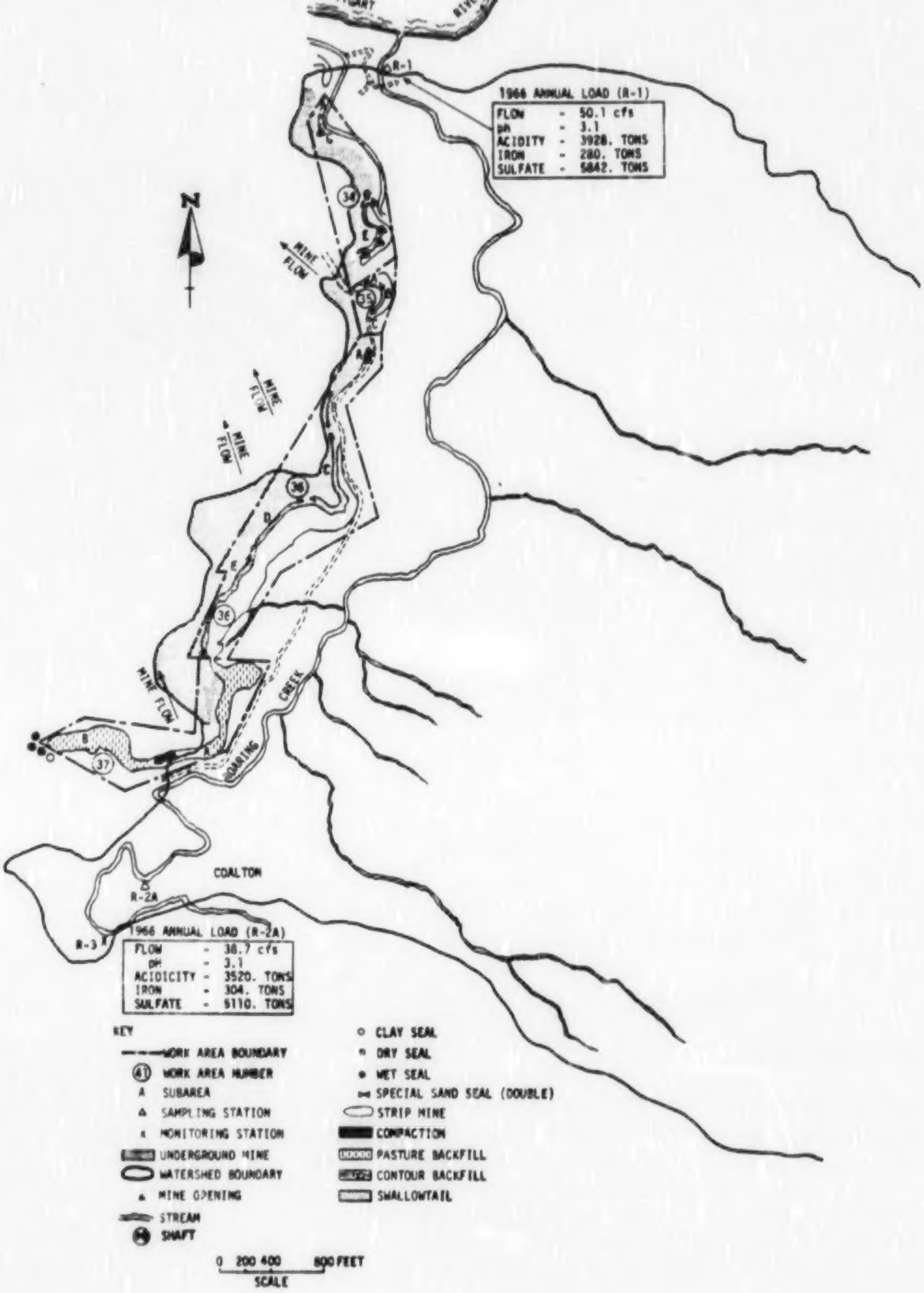
TYGART RIVER
R-1
1966 ANNUAL LOAD (R-1)
FLOW - 50.1 cfs
pH - 3.1
ACIDITY - 3928. TONS
IRON - 280. TONS
SULFATE - 5842. TONS
N
34
35
36
37
A
B
C
D
E
MINE FLOW
MINE FLOW
MINE FLOW
MINE FLOW
ROARING CREEK
COALTON
R-2A
R-3
1966 ANNUAL LOAD (R-2A)
FLOW - 38.7 cfs
pH - 3.1
ACIDICITY - 3520. TONS
IRON - 304. TONS
SULFATE - 5110. TONS
KEY
WORK AREA BOUNDARY
41 WORK AREA NUMBER
A SUBAREA
SAMPLING STATION
MONITORING STATION
UNDERGROUND MINE
WATERSHED BOUNDARY
MINE OPENING
STREAM
SHAFT
CLAY SEAL
DRY SEAL
WET SEAL
SPECIAL SAND SEAL (DOUBLE)
STRIP MINE
COMPACTION
PASTURE BACKFILL
CONTOUR BACKFILL
SWALLOWTAIL
0 200 400 800 FEET
SCALE

Figure A-16. Mouth of Roaring Creek (R-2A to R-1).

Mining Summary and Work Area Description

This watershed contained 55 acres of surface mines, which constitute 1.2 percent of the watershed. The surface mines, except for those on Rich mountain, were located far to the east and out of the study area, on the updip of the coal and therefore the underground mine drainage was away from the surface mines and toward the northwest to Grassy Run. Discharge was at GT1-1, GT1-2, and GT1-3 in Work Area 33 of Grassy Run.

Most of the strip mines had been graded so that the surface waters drained to the highwall and eventually to the underground mine, which eventually discharged at GT1-1, GT1-2, and GT1-3 in Work Area 33. No underground discharges were present in the watershed.

The surface mine on Rich Mountain in the Sewell seam (5 acres) had little if any effect on this watershed.

Details of the work areas within this watershed follow.

Work Area 34 (8 acres)--

Subarea A--A small area of subsidence.

Subarea B--A 150-foot prospect strip with no openings.

Subarea C--A caved opening.

Subarea D--A subsidence area. WPA possibly did some reclamation work here.

Subarea E--A 1,200-foot strip with at least three partially concealed openings along highwall. No discharge noted. Water may enter mine from this strip during wet weather. Very high spoil bank. Final cut has not been backfilled.

Work Area 35 - DDH No. 2 Strip (3.2 acres)--

Subarea A--A 16-foot partially caved opening with 3 feet of water on bottom and a large sink hole on the surface above the entry.

Subarea B--A long-abandoned strip with at least two concealed openings along highwall. A township road has been constructed across the spoil. A road above the highwall directed drainage to the strip area.

Work Area 36 - Bruno Rey Strip (29.7 acres)--

Subarea A--Two parallel openings along road, one of which was concealed. Entries were blocked by falls 100 feet from the outcrop. Openings were dry, and it did not appear that any water was entering the mine at this point.

Subarea B--An area of subsidence corrected by WPA.

Subarea C--Seventeen or more openings in highwall. The spoil was clean and drains to north.

Subarea D--A series of 25 or more concealed openings along face of highwall. Dirty spoil drained to the highwall.

Subarea E--A series of 24 or more concealed openings along highwall. Spoils were graded but poorly drained.

Subareas C, D, and E--This area was stripped and backfilled between 1960 and 1964. Although the strip had been well graded, the coal seam remained exposed, drainage was directed toward the highwall with inadequate ditching to the toe of the spoil, and excessive carbonaceous material remained exposed and was spread indiscriminately over the spoil area. Water drained into the underground workings from many points along the highwall.

Work Area 37 - North White's Run Strip (14 acres)--
Three partially concealed openings were noted along the highwall. The strip had been backfilled partially and was fairly clean, except for the northern end.

Description of the Mine Drainage Problem

This watershed, although large, is a small contributor to the pollution load at Roaring Creek. In the base year 1966, the average flow of Roaring Creek increased by 11.4 cfs from Station R-2A to R-1. Acidity and sulfate were increased by 408 tons and 731 tons, respectively. These contributions represented 10 to 12 percent of the entire pollution load. The iron load decreased by 24 tons.

Most of acid and sulfate being added comes from White's Run and the strip mine areas adjacent to the creek. Tables A-55, 56 and 57 summarize the water quality data of Roaring Creek as it enters (Station R-2A) and leaves (Station R-1) the watershed. Data on the quality of White's Run as it enters Roaring Creek were presented earlier in Appendix A.

Reclamation Work Performed

The only reclamation in this watershed was in Work Areas 37 and 36.

Work Area 37 - (14 acres)--
At Work Area 37A, 1,666 cubic yards of refuse material was placed in the strip pit and buried. Work Area 37B was then

TABLE A-55. SUMMARY OF ANNUAL DATA FOR STATION R-1, MOUTH OF ROARING CREEK, AND STATION R-2A, LOWER ROARING CREEK

Year	Flow, cfs	Acidity, tons	Iron, tons	Sulfate, tons
Station R-1				
Before reclamation				
1965	43.9	2,920	204	5,002
1966	50.1	3,928	280	5,842
After reclamation				
1968	51.9	3,728	279	5,046
1969	52.5	3,474	252	3,949
1970	52.2	3,383	244	3,495
1971	133.3	11,806	468	4,898
Station R-2A				
Before reclamation				
1965	32.0	2,670	281	4,480
1966	38.7	3,520	304	5,110
After reclamation				
1968	45.2	3,180	507	4,990
1969	34.2	2,550	328	3,560
1970	39.9	2,510	334	3,550
1971[a]	131.2	7,428	550	4,246

[a] Data for first nine months only.

TABLE A-56. SUMMARY OF QUARTERLY DATA FOR STATION R-1, MOUTH OF ROARING CREEK

Quarter	Flow in cfs				pH Value			
	1	2	3	4	1	2	3	4
Year								
1965	117.31	52.76	1.71	3.65	3.4	3.1	2.8	3.0
1966	55.52	81.24	9.89	53.75	3.2	3.1	2.8	3.2
1967	169.77	108.06	17.15	69.42	3.3	3.3	3.2	3.4
1968	52.27	99.83	6.72	48.75	3.4	3.6	3.1	3.2
1969	64.17	35.85	65.50	44.38	3.5	3.3	3.1	3.3
1970	95.50	51.00	13.23	49.18	3.4	3.0	3.4	3.6
1971	133.83	33.52	320.47	45.53	3.8	3.7	3.7	3.6
	Specific conductance in μmhos/cm							
1965	330	481	1,045	845				
1966	431	452	869	350				
1967	349	358	448	241				
1968	325	279	640	458				
1969	418	460	381	406				
1970	308	425	422	288				
1971	195	274	283	357				
	Acidity							
	Load in Tons				Concentration in mg/l			
1965	1,536	1,113	92	179	54	87	223	202
1966	1,091	1,498	492	847	81	76	205	65
1967	2,429	1,520	341	1,111	59	58	82	66
1968	875	1,356	244	1,253	69	56	150	106
1969	903	757	953	861	58	87	60	80
1970	1,343	1,051	237	752	58	85	74	63
1971	2,164	481	7,928	1,233	67	59	102	112
	Iron							
	Load in Tons				Concentration in mg/l			
1965	142	51	2	9	5	4	6	10
1966	94	99	22	65	7	5	9	5
1967	288	131	25	84	7	5	6	5
1968	101	73	10	95	8	3	6	8
1969	109	52	48	43	7	6	3	4
1970	116	62	6	60	5	5	2	5
1971	127	17	298	26	4	2	4	2

(continued)

TABLE A-56 (continued).

Quarter	Sulfate							
	Load in Tons				Concentration in mg/l			
	1	2	3	4	1	2	3	4
Year								
1965	2,732	1,868	156	46	96	146	376	278
1966	1,549	2,305	698	1,290	115	117	291	99
1967	3,911	2,490	919	1,330	95	95	221	79
1968	1,230	1,768	393	1,655	97	73	241	140
1969	1,307	809	1,144	689	84	93	72	64
1970	1,529	1,076	234	656	66	87	73	55
1971	914	401	2,876	707	28	49	37	64
	Hardness							
	Load in Tons				Concentration in mg/l			
1965	1,337	934	89	129	47	73	214	146
1966	646	1,143	357	769	48	58	149	59
1967	2,141	1,206	403	926	52	46	97	55
1968	710	969	187	958	56	40	115	81
1969	965	730	937	646	62	84	59	60
1970	1,205	495	199	740	52	40	62	62
1971	1,330	298	-	758	41	37	-	69
	Calcium							
	Load in Tons				Concentration in mg/l			
1965	-	755	53	78	-	59	128	88
1966	417	650	202	482	31	33	84	37
1967	1,071	681	225	505	26	26	54	30
1968	443	678	137	532	35	28	84	45
1969	700	469	445	388	45	54	28	36
1970	718	445	141	394	31	36	44	33
1971	682	221	2,617	387	21	27	34	35
	Aluminum							
	Load in Tons				Concentration in mg/l			
1965	-	90	7	15	-	7	17	17
1966	67	99	36	52	5	5	15	4
1967	165	157	29	67	4	6	7	4
1968	76	97	21	130	6	4	13	11
1969	78	43	64	65	5	5	4	6
1970	93	37	16	72	4	3	5	6
1971	119	17	622	64	4	2	8	6

TABLE A-57. SUMMARY OF QUARTERLY DATA FOR STATION R-2A, LOWER ROARING CREEK

	Flow in cfs				pH Value			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	86.37	36.85	1.52	3.43	3.4	3.1	2.8	3.0
1966	43.83	58.77	9.36	43.00	3.2	3.1	2.8	3.3
1967	128.86	78.10	15.04	48.49	3.4	3.3	3.3	3.4
1968	59.40	77.25	4.37	39.85	3.4	3.6	3.1	3.5
1969	35.70	21.33	46.85	32.92	3.4	3.3	3.2	3.4
1970	73.83	36.83	10.58	38.23	3.4	3.2	3.4	3.6
1971	93.00	28.40	272.11	-	3.8	3.5	3.6	-
	Specific conductance in µmhos/cm							
1965	326	537	1189	781				
1966	399	424	877	294				
1967	320	362	449	262				
1968	312	268	750	340				
1969	356	396	311	333				
1970	279	370	455	243				
1971	160	286	300	-				
	Acidity							
	Load in tons				Concentration in mg/l			
1965	1288	109[illegible]	107	180	60	121	286	214
1966	1036	1319	510	652	96	91	222	62
1967	1919	1347	363	809	61	70	98	68
1968	1008	1216	220	736	69	64	205	75
1969	665	517	751	618	76	99	65	77
1970	1035	721	229	527	57	80	88	56
1971	1353	399	5676	-	60	58	86	-
	Iron							
	Load in tons				Concentration in mg/l			
1965	140	118	9	14	7	13	25	17
1966	106	121	35	42	10	8	15	4
1967	221	143	41	107	7	7	11	9
1968	148	234	29	96	10	12	28	10
1969	100	68	81	79	11	13	7	10
1970	144	66	29	95	8	7	11	10
1971	113	41	396	-	5	6	6	-

(continued)

TABLE A-57 (continued).

	Calcium							
	Load in tons				Concentration in mg/l			
Quarter	1	2	3	4	1	2	3	4
Year								
1965	-	771	59	78	-	86	159	93
1966	362	539	117	359	34	37	77	34
1967	930	523	213	428	29	27	58	36
1968	486	584	100	414	33	31	94	42
1969	428	302	517	351	49	58	45	44
1970	643	388	148	377	36	43	57	40
1971	518	214	2904	-	23	31	44	-
	Aluminum							
	Load in tons				Concentration in mg/l			
1965	-	107	8	15	-	12	21	18
1966	68	83	37	49	6	6	16	5
1967	161	95	28	59	5	5	7	5
1968	64	88	17	110	7	5	16	11
1969	63	36	73	57	7	7	6	7
1970	83	36	16	59	5	4	6	6
1971	90	28	-	-	4	4	-	-
	Sulfate							
	Load in tons				Concentration in mg/l			
1965	2165	1869	181	263	102	207	485	312
1966	1436	1914	710	1053	133	133	309	100
1967	3278	2189	645	1130	104	115	175	95
1968	1554	1803	298	1334	107	95	278	137
1969	1004	602	1090	864	115	115	95	107
1970	1388	905	276	980	77	100	106	105
1971	880	462	2904	0	39	67	44	-
	Hardness							
	Load in tons				Concentration in mg/l			
1965	1069	920	97	130	50	101	259	154
1966	583	941	316	613	54	65	137	58
1967	1732	951	386	749	56	49	104	63
1968	806	890	153	731	55	47	142	74
1969	668	492	864	603	76	94	75	74
1970	1071	488	197	725	59	54	75	77
1971	1037	282	-	-	41	41	-	-

graded to a pasture backfill. In October 1967, agricultural limestone was applied at a rate of 2 tons/acre. The area was "frost seeded" in March 1968. The seed mixture (10 lb birdsfoot trefoil, 10 lb orchard grass, 10 lb Kentucky bluegrass, and 5 lb sweet clover) and fertilizer were broadcast on the surface of the frozen ground. Freezing and thawing action then moved the seed into the soil surface. The outslope was hydroseeded in May 1968.

All the plants show vigorous growth. A large number of locust trees have volunteered into the area. The area may be considered stabilized.

Work Area 36 (21 acres)--

No regrading took place. In the spring of 1968, the area was prepared and seeded with 1 lb tall fescue, 9 lb perennial rye grass, 10 lb weeping love grass and 1 lb alsike clover.

The area also received 1000 lb of 10-10-10 fertilizer and 3 tons/acre of limestone. The growth was spotty, good in some areas and poor in others. The situation was complicated by the owner turning cattle loose during the first year. This area is only partially stabilized.

Cost of Work

Records were kept of equipment and labor used in each work area. These data were used to determine the direct cost as reported in Table A-58. The remaining costs were then distributed on a direct-cost percentage basis to the work areas. For the cleaning and grubbing, reclamation, and underground activities, the total cost was 1.297 times the direct cost. Total revegetation costs were determined in a similar manner. Total cost for each work area is reported in Table A-59.

Results of Reclamation

Water quality data for 1970 showed the pollution contribution of the watershed to be 873 tons of acid with sulfate and iron load decreases of 55 tons and 90 tons (Table A-55). The flow contribution remained nearly the same (12.3 cfs average) as for the base year 1966. No decrease in acidity was realized as a result of the grading, revegetation and mine sealing, but the contribution of sulfate had been cut significantly. Data for 1971 showed an extremely high pollution load as a result of severe flooding in September 1971.

TABLE A-58. COST OF WORK - DIRECT COST (DOLLARS)[a]

Area No.	Cleaning and grubbing		Reclamation		Underground		Revegetation		
	Equipment	Labor	Equipment	Labor	Equipment	Labor	Equipment and materials	labor	Total
36	-	-	-	-	-	-	4,011	1,980	5,991
37	0	1,504	8,723	2,303	0	575	1,369	124	14,598

[a] For Cleaning and Grubbing, Reclamation and Underground, this includes only the actual cost of equipment and labor and does not include any materials, overhead, G & A, etc. Revegetation Cost includes cost of labor, equipment and materials.

TABLE A-59. TOTAL COST FOR WORK AREAS IN THE LOWER ROARING CREEK WATERSHED (DOLLARS)

Area No.	Cleaning and grubbing, reclamation, underground	Revegetation	Total	Cost/acre
36	-	7,776	7,776	370
37	17,007	1,863	18,870	1,348

APPENDIX B

LEASE AGREEMENT

WITNESSETH: That in consideration of the benefits which may accrue to the Grantors from the Acid Mine Drainage Demonstration Project in Roaring Creek District, Randolph County, West Virginia, the Grantors do hereby grant and convey unto the Grantee the right to enter upon that certain tract of land with full rights of ingress, egress and regress upon said land for the purpose of performing such work as may be required for planning completing said demonstration project, and do hereby grant and convey to said Grantee the following rights, rights of way and easements pertaining to the surface of said land:

a. To construct access roads to sites where work will be performed by man and equipment.

b. To remove garbage, debris, and obsolete mine buildings and equipment from areas where work is to be performed to a place of disposal as agreed upon by the parties hereto.

c. To backfill, grade, and ditch in strip mine areas with the understanding that vegetation and trees will be planted on reclaimed areas.

d. To divert surface drainage to prevent its percolating underground; to build lined channels; and to build ponds for purposes of testing water treatment methods, effects on fish, etc. (Prior to completion of the work under this paragraph, the State will notify the grantors in writing of said completion date, and at that time the said grantors will have the right if they so desire and so state in writing within 15 days after receipt of said notice, to have any ponds constructed under this project to be left intact for the use of said grantors. In the event the grantors do not elect to have any ponds remain intact of if such election is not exercised as aforesaid, the pond will be drained, backfilled with earth and revegetated).

e. To cut trees, remove stumps, and borrow earth in vicinity of strip mine areas where such must be done to complete backfilling and seal rock cracks in the highwall, with the understanding that trees are to be cut in suitable lengths and piled at a location readily accessible to the Grantors for trucking.

f. To chemically grout with suitable equipment rock cracks within surface subsidence holes, and, as in item d, cut trees, remove stumps within surface subsidence holes, and backfill and compact the holes to obtain satisfactory drainage over the fill material.

g. To conduct an experiment to determine the effectiveness of chemically grouting surface subsidence holes within wooded areas using a core drill, truck and other portable equipment.

h. To reconstruct or cap gob piles to prevent or minimize water entry into them.

i. To seed in a cover crop of grass and legume, and to plant brush and trees to provide soil stabilization.

j. To apply soil amendments to promote growth of vegetation; substances which may be used include agricultural fertilizers, digested sewage sludge, distillery wastes, sawdust, wood chips, limestone, and fly ash.

k. To drill test holes and conduct pumping and other tests to gain information on subsurface rock formations and on groundwater movement; with the understanding that these holes will be filled or sealed or capped at the end of the study period.

For the consideration aforesaid, the following rights, rights of way and easements are hereby granted with relation to the subsurface of said land:

a. To conduct an experiment in construction of masonry air seals in mine openings using cinder blocks mortared and faced for sealing with rigid urethane foam to determine the cost and effectiveness.

b. To seal mine openings within to-be-reclaimed strip areas by layer compaction of suitable soil against openings filled with collapsed and crushed rock, prior to totally backfilling and grading of these areas.

c. To do the same as in item b, but using masonary for seals, where it is practical to clean out the caved rock in the openings and in the entries to the point in the mine where the roof, ribs, and bottom are reasonably firm.

d. To construct masonry seals in certain mine openings with or without water traps outside of strip mine areas.

All rights, rights of way and easements herein granted are for the purpose of permitting the Grantee to do the things hereinbefore set forth, all for the purpose of planning, developing, monitoring, completing and demonstrating the project for a period of ten years. It is covenanted by the Grantors that they will not voluntarily do any act or permit any act to be done that will destroy any portion of the complete demonstration project until the rights, rights of way and easements herein granted have terminated as aforesaid.

APPENDIX C

ANALYTICAL PROCEDURES

SOIL

Specific conductance and pH were performed on a 1:1 soil-distilled water paste. Aluminum, manganese, and iron were determined on a KCl extract using atomic absorption. Potassium was determined on a H_2SO_4 extract by atomic absorption. Exchange acidity was determined on a KCl extract titrated with NaOH to pH 8. Phosphorous was determined on a H_2SO_4 extract by the method outlined by Black, et al., (1965-P. 1,040). Sulfate was determined on a KCl extract by American Public Health Association (1965-P. 291) method.

WATER

Acidity was measured by the hot method to an end point of pH 8.2. Iron, aluminum, calcium, and magnesium were determined by atomic absorption. Hardness was the summation of calcium and magnesium. Sulfate was determined by the American Public Health Association (1965-P. 291) method.

APPENDIX D

ASSOCIATED REPORTS

A number of reports (both published and unpublished) were generated as a result of the Elkins Mine Drainage Pollution Control Demonstration Project. Appendix D presents a list of these associated reports:

1. Committee of Public Works, U.S. House of Representatives. 1962 Acid Mine Drainage. House Committee Print No. 18, 87th Congress, Second Session. U.S. Government Printing Office: Washington, D.C., p. 24.

2. Hill, Ronald D. The Effectiveness of Mine Drainage Pollution Control Measures, Elkins, West Virginia. U.S. Department of Interior. Federal Water Pollution Control Administration. ACS Division Fuel Chemical Preprints, 13(2), 103-15. 1965.

3. Joint Federal-State Acid Mine Drainage Pollution Control Program. Annual Progress Report Fiscal 1965. U.S. Department of Interior - Bureau of Mines, Geological Survey, Bureau of Sport Fisheries and Wildlife.

4. Bullard, W.E., "Acid Mine Drainage Pollution Control Demonstration Program," Uses of Experimental Watersheds. International Assocation of Scientific Hydrology, Symposium of Budapest. Extract of Publication No. 66. Budapest, Hungary, 1965.

5. Burner, C.C. Progress Report - Fishery Management Program. Roaring Creek-Grassy Run, Randolph Co., West Virginia (Mimeo). p. 10. 1967.

6. Hill, R.D., "Reclamation and Revegetation of 640 Acres of Surface Mines-Elkins, West Virginia," Proceedings, International Symposium on Ecology and Revegetation of Drastically Disturbed Areas. Pennsylvania State University, August 1969 (released 1970).

7. Hill, Ronald D. Limestone Mine Seal. Mine Drainage Pollution Control Branch. U.S. EPA, Cincinnati, Ohio. March, 1970.

8. Hill, Ronald D., Elkins Mine Drainage Pollution Control Demonstration Project. Proceedings Third Symposium on Coal Mine Drainage Research. Mellon Institute, Pittsburgh, Pennsylvania. May, 1970.

9. Scott, Robert B., Ronald D. Hill, and Roger C. Wilmoth. Cost of Reclamation and Mine Drainage Abatement, Elkins Demonstration Project. Water Quality Office. U.S. EPA. Robert A. Taft Research Center, Cincinnati, Ohio. 1970.

10. Warner, Richard W. Distribution of Biota in a Stream Polluted by Acid Mine-Drainage. Ohio J. Science. 71(4):202-215. 1971.

11. Hill, Ronald D. and John F. Martin. Elkins Mine Drainage Pollution Control Demonstration Project - An Update. Proceedings Fourth Symposium on Coal Mine Drainage Research. Mellon Institute, Pittsburgh, Pennsylvania. April, 1972.

12. Wilmoth, Roger C., Robert B. Scott and Ronald D. Hill. Combination Limestone-Lime Treatment of Acid Mine Drainage. Proceedings 4th Symposium on Coal Mine Drainage Research. Mellon Institute, Pittsburgh, Pennsylvania. 1972.

13. Plass, Wm., and Vogel, Willis. Demonstration and Experimental Plots on Rich Mountain, a series of unpublished progress reports from 1965 thru 1967. U.S. Department of Agriculture, Northeast Forest Experiment Station.

14. Itek Optical Systems Division. Toxic Soil Photoanalysis Investigation, final report for FWPCA. P.O. No. 67-2-108, January, 1968.

15. Findlay, Charles. Grouting Surface Subsidence Areas Over Abandoned Deep Mines Above Drainage. U.S. Bureau of Mines. In-House Report, May, 1966.

16. Johns-Manville Research and Engineering Center. Precoat Filtration of Neutralized, Settled Mine Drainage Underflow at Norton, West Virginia. USBM Contract No. 14-09-0050-2931, Johns-Manville Report No. 412-8014, December, 1966.

17. Halliburton Company. New Mine Sealing Techniques for Water Pollution Abatement. Federal Water Quality Adminstration Contract No. 14-12-453, March, 1970.

18. Burner, Charles. Fishery Management Program-Acid Mine Drainage Pollution Control Demonstration Project No. 1. Bureau of Sport Fisheries and Wildlife. Progress Report, July 1967.

19. Treatment and Revegetation of Test Plots on Reclaimed Surface Mines. In-House Report. U.S. Environmental Protection Agency, Cincinnati, Ohio.